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SOME OF THE PAVILIONS OF THE RUDOLF VIRCHOW HOSPITAL.

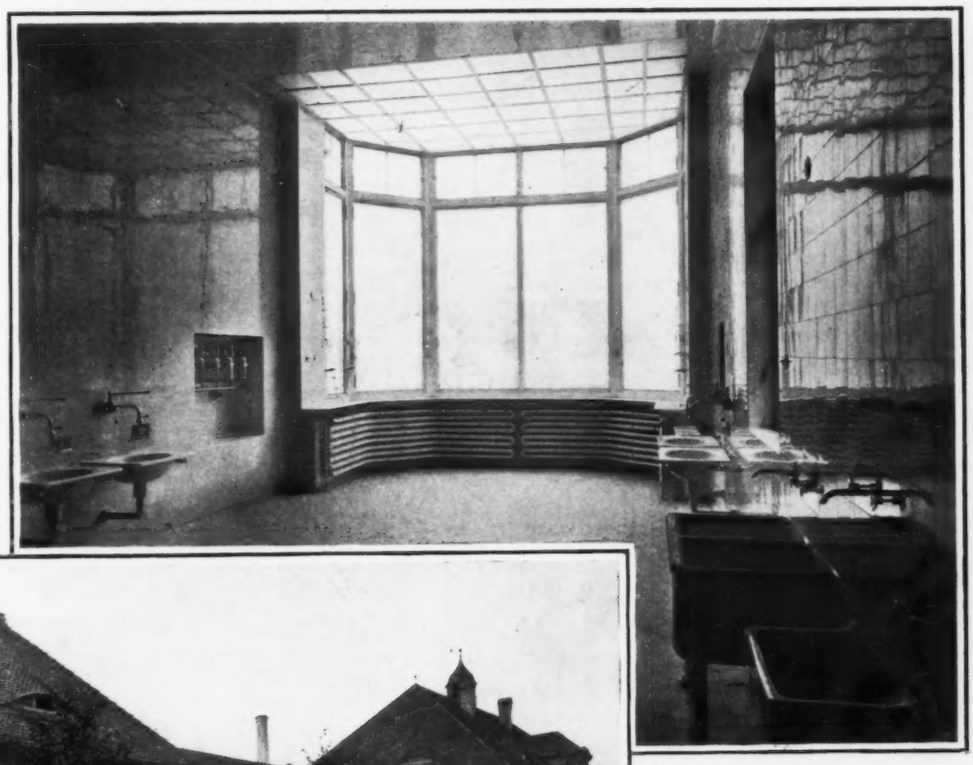
THE RUDOLF VIRCHOW HOSPITAL.*

By WILLIAM MAYNER.

THE Rudolf Virchow hospital in Berlin is so designated from the famous medical savant and well-known citizen of that name. The hospital is situated on the northern boundary of the city, close to the Spandau Canal and opposite grounds which will not be built upon, so that quiet and good air are secured for all future time.

The plan of the hospital was laid out by Ludwig Hoffmann. It comprises fifty-seven separate buildings with 2,000 beds for patients of both sexes. The lying-in hospital contains 220 beds; that for patients with internal complaints, 500; 564 beds are available for those whose cases are of a surgical nature; mental patients, 18 beds; those with sexual complaints 520 beds, and infectious diseases 178. Together with the attendants and the school for nurses, the hospital will contain about 2,800 people. Two main roads planted with trees divide the hospital into four blocks, separating the pavilions for surgical and internal complaints and the male and female divisions. Each pavilion contains rooms for the beds on the ground floor and is raised centrally on the first floor for the rooms of the attendants.

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.



OPERATING ROOM.

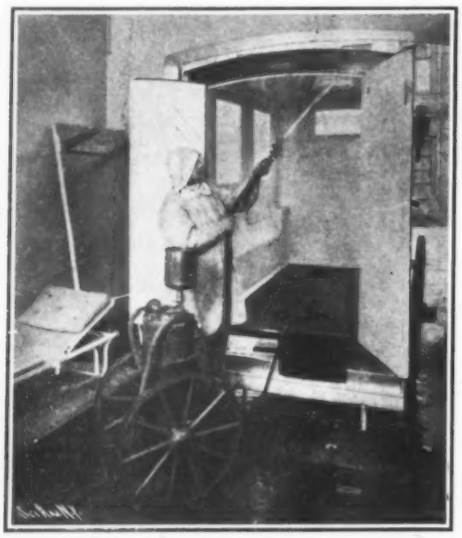
ONE OF THE FIFTY-SEVEN BUILDINGS OF THE NEW RUDOLF VIRCHOW HOSPITAL.

THE RUDOLF VIRCHOW HOSPITAL AT BERLIN.

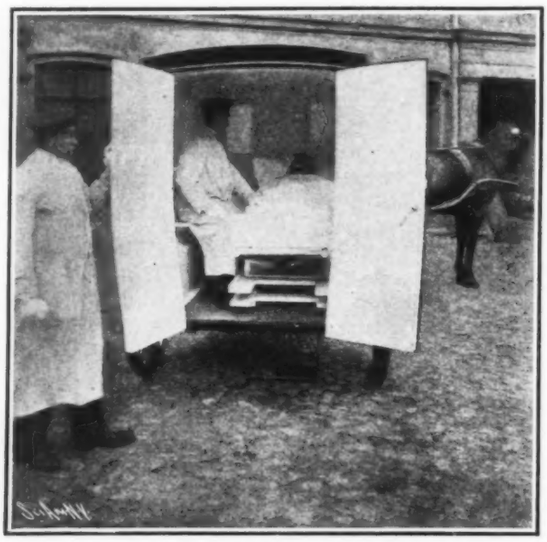
The bathing house contains a medico-mechanical institute, a dispensary, and the operating house, the latter comprising four operating halls, each connected by a gangway with the neighboring pavilions of the male and female divisions. At the back of the operating house there is a building for examination and treatment by Röntgen rays.

The hospital has its own water works and an engine house with a plant for the production of ice. Near the stables

for animals kept for experimental purposes there is a building for disinfecting and burning articles. The division for contagious diseases lies separated from the other buildings and has a separate entrance. It is composed of a quarantine pavilion, a pavilion for diphtheria and four others, and one for post-mortem examinations. A little park gives convalescent patients an opportunity to enjoy the fresh air. All the sick-



CLEANING AND DISINFECTING A BERLIN AMBULANCE.



TRANSPORTING A PATIENT TO THE HOSPITAL IN A BERLIN AMBULANCE.

rooms lie so that they get the sun, and the large halls as a rule receive light from two sides. The pavilions lie a little way from the roads, from which they are separated by hedges. The heating is effected by means of warm water, which is carried by a subterranean canal large enough for a person to walk through. The building of the hospital was commenced in the fall of 1899, and completed in the summer of 1906, so that the whole time of building amounted to not quite seven years and a half. The total cost of the building, furniture, installation, etc., amounted to $8,500,000. The grounds are 257,000 square meters in extent. The architecture is simple, and vivid colors have been avoided. There are electric works for the production of light and power (ventilators, elevators, etc.). The rooms are aired by special arrangements for conducting in good air and drawing out the impure air. Water, which is obtained from two wells within the grounds of the hospital, is freed from iron and is filtered.

THE PRESERVATION OF EGGS.

By DR. O. SCHUETTE.

THE contents of an egg, so rich in albuminous matters and hence prone to decay, are apparently well protected against the air by a fairly strong shell, consisting essentially of calcium carbonate. On examining this shell, however, with the aid of a magnifying glass, we readily notice that it has numerous pores permitting the communication of the living egg with the outside atmosphere. It is through these pores that evaporation proceeds and infection may enter. As water evaporates through these pores from the dead egg, air passes in to take its place, and the bacteria entering with this air soon perforate the inner membrane of the shell and rapidly grow and multiply in the albuminous medium.

But even in the oviduct of the hen the microbes that cause the decomposition of the egg's contents may gain entrance, and as a rule this occurs during impregnation, as is shown by the fact that non-fertilized eggs keep better than those that are fertilized.

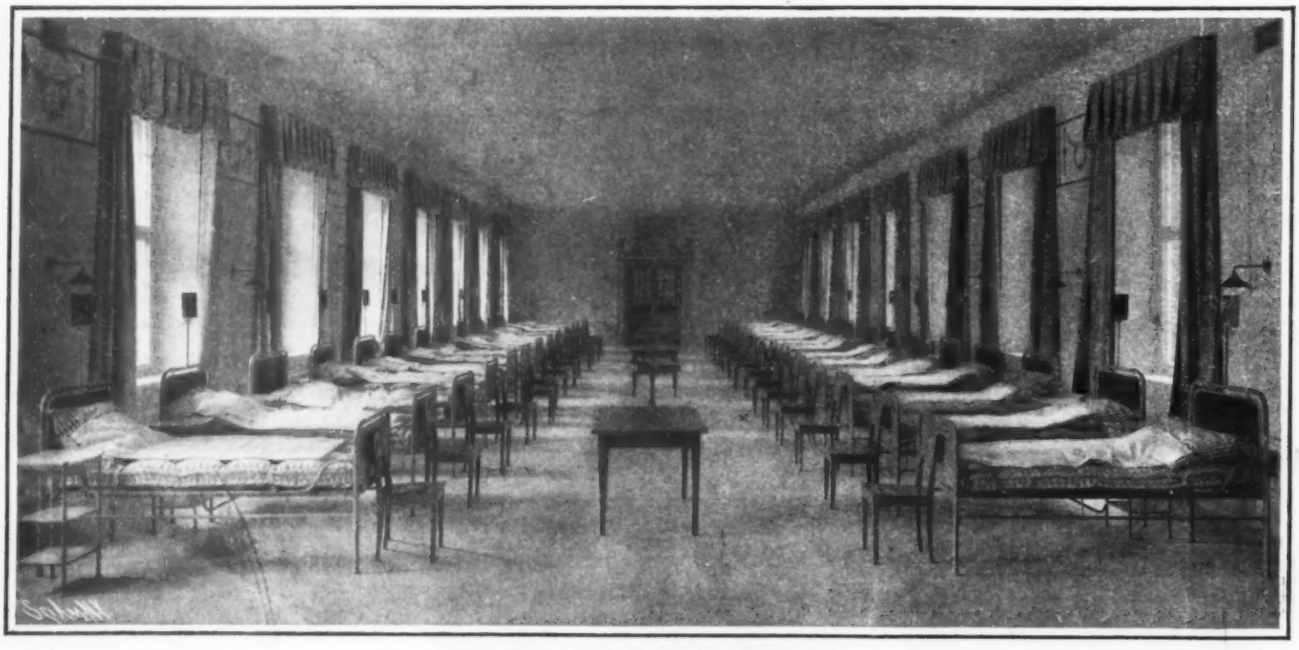
Like most of our articles of food, therefore, eggs are perishable, and since hens are most prolific during the warmer season, the supply of eggs then is largely in excess over the demand, and it becomes necessary to preserve the surplus in order to render this nutritious food available at other seasons. The methods employed for this purpose are different from those adapted for other food stuffs, as it is impossible to reach the contents of the egg without destroying its shell. Sterilizing or pasteurizing of eggs is precluded on account of the ready coagulation of the albumen, even at temperatures far below boiling. In preserving eggs no attempt is made to kill the germs they already contain, but the aim is to prevent their growth and exclude other germs. There are two methods of preserving eggs, viz., cold storage and protection from the air.

It is sometimes recommended to thoroughly clean all eggs intended for prolonged storage. It goes without saying that any adhering dirt, like dried excrements of the fowl, should be carefully removed, but even the freshly laid and apparently clean eggs are frequently covered with mold fungi. Eggs may be readily and effectively cleaned by means of specially designed apparatus. It consists, essentially in a circular disk which can be made to rotate very rapidly, and which carries brushes forming an hemispherical depression. The eggs are pressed against the revolving brushes, while a strong jet of water is directed on the shells.

Some consider this washing indispensable, while others declare that it impairs the keeping qualities of the eggs. For nature has provided the egg shell with a mucilaginous coating which, it is claimed, prevents the entrance of bacteria and thus tends to preserve the egg. This coating is readily removed by washing, leaving the egg without its natural preservative.

Preservation by cold storage depends on checking the growth of such micro-organisms as would bring about decomposition of the egg. To thrive and multiply these fungi require suitable temperatures, which, however, differ with the different species. While higher temperatures actually kill these micro-organisms, cold merely brings about a suspension of their vital functions. Some dealers preserve their eggs at temperatures of 5 to 7 deg. C., while others prefer to keep them at a freezing temperature. To this end the eggs are placed in water-tight (or even air-tight) boxes which are completely surrounded by ice. Each box contains a number of drawers provided with racks of tin-plate, in the holes of which the eggs are placed with the points down.

It would appear that the temperature at which eggs are kept is not without influence on their keeping quality after they are taken out of cold storage; thus it is claimed that eggs which had been stored at 0 deg. C. decayed more rapidly than others which had been kept at a somewhat higher temperature. Eggs that are stored in a suitable manner at temperatures near freez-



A WARD IN THE NEW RUDOLF VIRCHOW HOSPITAL.

THE RUDOLF VIRCHOW HOSPITAL AT BERLIN.

ing suffer but slightly in quality. It is claimed even that after being left in cold storage for a year, they still possess the odor and taste of fresh eggs. To prevent the yolks from adhering to the shell, it is necessary from time to time to turn eggs kept in storage. A new apparatus for preserving eggs has recently been submitted by Hermann Podolsky* to the German Patent Office; its object is to effect an automatic turning of all the eggs in a container. Each layer of eggs is firmly held in place by movable pairs of frames, and these may be turned at pleasure through angles of 90 or 180 deg. The turning is said to be especially necessary during the first few days to bring the yolks to the centers of the eggs. They will not cling to the shells when the turning is repeated a number of times.

As above stated, the micro-organisms to which the spoiling of eggs is due may find their way into the egg in two ways; either by passing through the pores of the shell or while the egg is being formed in the oviduct. When eggs are preserved by cold storage, it seems to make little difference whether or not microorganisms are already present; the cold effectually checks the growth of such germs. It is different with the methods in which the preservation of the eggs depends on exclusion of air, and particularly in those cases where the eggs are packed in dry solid materials. While this may prevent the entrance of new germs, the destruction of the contents of the egg by microorganisms already present cannot be prevented. According to Zoerkendoerfer† the bacteria producing putrefaction in eggs are decidedly aerobic and for this reason the spoiling of eggs may be somewhat retarded. The poor results that have been recorded when eggs were packed in dry materials may thus be accounted for. Among such materials we mention chaff, bran, sawdust, dry sand, ashes, charcoal powder, and salt. The three substances first mentioned are probably least effective in excluding air; for eggs packed in them generally acquire a disagreeable odor and taste. Charcoal is employed either in the form of powder or in small pieces; when it has been freshly ignited it is an effective preservative, no doubt owing to its power of absorbing large quantities of oxygen. Boeckmann recommends wrapping the fresh eggs in unsized paper and to keep them in a box placed in a cool cellar. The results obtained in this way have not always been satisfactory. An objection to all these methods of packing eggs is that the materials absorb moisture from the egg contents and thus gradually impair the freshness of their flavor.

To avoid this, various attempts have been made to protect the eggs from the air by coating the shells with air-tight substances. A method which has long been in use is to coat eggs with calcium carbonate. This is done by immersing the eggs in lime water and then allowing them to dry in the air. A uniform coating of calcium hydrate is left on the shells, and by absorbing carbonic acid from the air this changes into carbonate which sets and closes the pores. But even when the dipping and drying are repeated, the desired end is not always accomplished; the pores are not entirely closed, water evaporates from the interior and the eggs lose in weight. Much better results have been obtained by means of water glass. The fresh eggs are placed into a concentrated, slightly warm solution of sodium silicate and allowed to remain in it for about half an hour. They are then drained off and allowed to dry in the air. The alkaline silicate reacting with the calcium carbonate of the shell forms sodium carbonate and calcium silicate, which latter forms a uniform and impervious coating over the shell. Potash water glass is not available for this purpose, owing to the deliquescent nature of the potassium carbonate that would result.

In the two methods just described the impervious coatings are produced by chemical reactions; the same object can also be obtained by purely chemical means. By dipping the eggs into dilute alcoholic solution of glycerin and salicylic acid (or boric acid) and subsequent drying, their shells are provided with a preservative coating. Other substances that have been tried are shellac, gum arabic, gelatin, paraffin, and vaseline, but although the air may have been more or less successfully prevented from passing through the pores, the coatings cannot altogether prevent the growth of the bacteria present in the eggs, and most of the substances named have not given satisfactory results in practice.

Since the production of egg coating is a time-consuming operation and does not always accomplish the desired purpose, it is often preferred simply to place the eggs into a preservative liquid. This is certainly more convenient, though there are also certain objections to it. When the egg is exposed to the air, there is a constant exchange of gases between the contents and the atmosphere, such diffusion being permitted by the shell, but when the egg is immersed in a liquid, constituents escaping through the pores pass into this liquid and constituents of the latter may penetrate into the egg. Small amounts of preservatives may thus be introduced into the egg; the good results that have been obtained by the method in question are thus explained, but it has also been noticed that on continued storage in preservative solutions, eggs acquire a more or less pronounced disagreeable taste. This applies especially to eggs packed in lime water, a liquid which was formerly used very extensively for this purpose. The preservative properties of lime water, so far as the storage of eggs is concerned, are very strong; eggs can be kept for months in it without any signs of spoiling. Nevertheless the taste of the eggs suffers and after a certain amount of lime has diffused through the shells, the whites of eggs can no longer be beaten to a froth. The diffusion of lime may be reduced by adding salt to the lime water until the density of the liquid is equal to that of the contents of the eggs. It is claimed that eggs can be kept in such a solution for half a year without detriment to their taste.

The changes that take place in the substance of eggs when these are stored in lime water are both physical and chemical. Ivan Roeszenyi* has made experiments on eggs preserved in milk of lime. He states that an egg which had been immersed for eleven months in the preserving liquid had lost both in weight and specific gravity, its ash was also found diminished, but the lime content of the latter had risen to 15.21 per cent. From his experiments Roeszenyi concludes that the best criteria for distinguishing between lime-preserved and fresh eggs are afforded by the albumen contents and the percentages of lime found in the ash.

The solutions now most frequently used for preserving eggs are those of the alkaline silicates, known as water-glass. The commercial viscous solution is diluted for this purpose with ten times its volume of water, and the solution so obtained is poured over the eggs. This is conveniently done in barrels provided with movable shelves having round holes to receive the eggs. After the latter have been placed in the racks with the points down, the racks are put into the barrel. The barrel is then filled with the water-glass solution. When kept in a cool place, the eggs are said to remain perfectly fresh for one and one-half years. The eggs so treated are said to break easily on boiling, but this may be prevented by piercing the shell with a needle.

Less efficacious than water-glass are the solutions of glycerin and salicylic acid (or boric acid). It does not appear that they have been successfully applied on a large scale. The results obtained with salt solutions are likewise unsatisfactory; eggs preserved in brine acquire a salty taste after a few days, and on prolonged storage become unfit for consumption without undergoing putrefaction.

Two other processes for preserving eggs may be briefly mentioned. The one consists in dipping the eggs for ten to twenty seconds into boiling water; the other in immersing the eggs for one hour in a solution of permanganate of potash. After drying, they are wrapped in clean paper and stored in a dry, cool place. The last-named method has been highly recommended, but neither method has found extended application.

Some years ago quite a number of methods of preserving eggs were treated in Germany. The best results were obtained by packing the eggs either in lime water or in water-glass solution, and, curiously enough, by coating with vaseline. None of the eggs preserved by any of these methods spoiled, but all the other methods gave unsatisfactory results. It should be noted, however, that the methods tested did not include cold storage. This and packing in water-glass are at present undoubtedly the most successful methods of preserving eggs. That even these methods leave something to be desired is shown by the fact that new processes are constantly proposed and tried. Among those recently published, two patented inventions deserve notice.

Process of Drs. L. Mach and W. Pauli, Vienna:†

The eggs are first treated with a disinfecting liquid, then thinly coated with a mixture essentially consisting of paraffin, linseed oil, turpentine, and fats. Eggs treated in this way are said to keep for a long time without being impaired in their appearance, odor, taste, or their behavior on boiling.

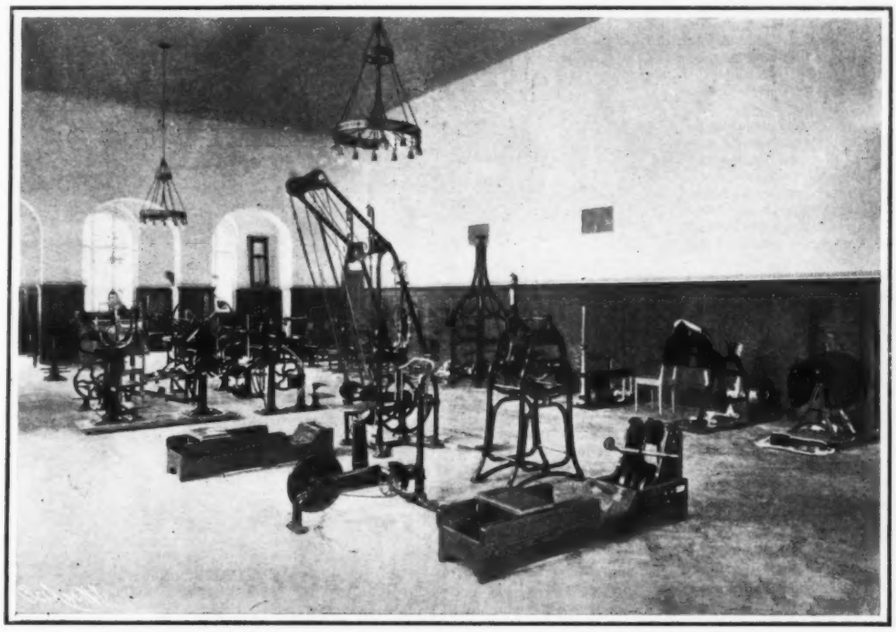
Process of Drs. L. Mach and W. Pauli, Vienna:*

The eggs are cleaned in the usual manner and impregnated in a vacuum with a melted material, like paraffin or wax, kept at 40 to 50 deg. C. When atmospheric pressure is restored the impregnating material is forced through the pores of the shells, so that upon cooling a protecting layer forms on the inner side. This treatment does not in the least affect the taste of the eggs.—Pure Products.

* Konservenzeitung, 1906, p. 355.
† Archiv fuer Hygiene, 1903, 16, 396.

* Chem. Zeitung, 1904, 620-621.

* Chem. Centralblatt, 1906, p. 658.
† Zeitschr. f. U. d. Nahr. u. Genussmittel, 1906, part 12.



MEDICO-MECHANICAL INSTITUTE IN THE NEW RUDOLF VIRCHOW HOSPITAL.

THE RUDOLF VIRCHOW HOSPITAL AT BERLIN.

Skates have been invented which will fold perfectly flat and to such small dimensions that they can be carried in the pocket. A leather wallet with two pockets is supplied with each pair, and when closed the package is three-fourths of an inch wide, one inch thick and the length of the skates.

THE INSTALLATION AND ADJUSTMENT OF A 100-MILE WIRELESS TELEGRAPH SET.—III.*

By A. FREDERICK COLLINS.

THE installation of the equipment may be begun by placing the Edison primary cells under the instrument bench and preferably on a platform 6 or 8 inches in height rather than directly on the floor where they would be subjected to breakage by accident. Having coupled the cells up in series insulated leads are brought up to the large binding posts *A* and *B* on top of the bench, as shown in the top elevation, Fig. 1.

The induction coil is mounted on the bench at the extreme left with its longitudinal axis at right angles to the length of the bench, for it not only takes up less room when set in this position, but the connections, both primary and secondary, are more easily made and without the wires crossing each other. The binding post *A* is connected with the terminal of the primary winding of the induction coil nearest to it, while the opposite terminal leads to one of the binding posts of the independent interruptor, which is set about midway between the induction coil on the left and the receptor on the right.

To the left of the interrupter is placed the box containing the compensating capacity or condenser that is connected across the main circuit contacts of the device, and to the right of the interruptor is the large Morse key which is connected with one of the binding posts of the interruptor. The opposite post of the key leads to a small knife switch capable of carrying 20 or 25 amperes and the primary circuit is completed by connecting the opposite terminal of the switch with the binding post of the battery marked *B*.

It will be observed that the condenser, the interruptor, the key, and the switch, are placed near the front of the bench and in alignment with each other, while at the rear of the bench the induction coil, the adjustable spark-gap, the Leyden jar battery, and the tuning inductance coil of the sender are also lined up in sequence. The aerial switch for throwing in and out the transmitter and the receptor is dropped a little below the line of the other high-tension instruments as well as a trifle to the right of the key immediately in front of it.

The tuning coil of the receiver follows in a line to the right of the aerial wire switch and to the extreme right is placed the receptor. The receptor, it may be said, comprises a small box in which are set the dry cells, the coils of the 10-ohm and 150-ohm resistances of the rheostats forming the potentiometer, and the condenser. On top of the receptor box, which may conveniently measure 3½ inches in height, 6½ inches wide, and 7 inches in length, is mounted the microphone detector, as well as the necessary levers for the resistance coils, the battery switch, and finally the binding posts for connecting in the aerial and earth wires and the telephone receiver.

Referring to the top elevation illustrating the disposition of the various parts of the sending and receiving apparatus it will be seen that two and three wires apparently connect the tuning inductance coils with the same contact posts on the aerial switch.

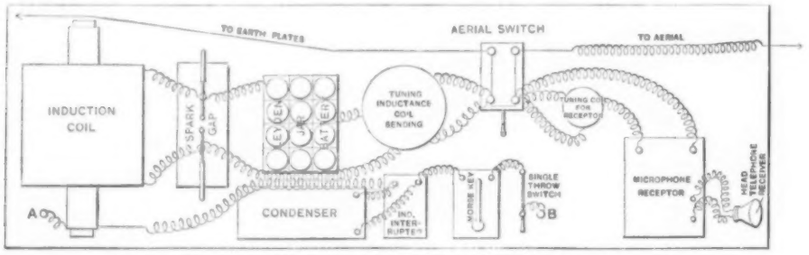


Fig. 1.—Plan View of Instrument Bench, Showing Disposition of Apparatus.

This is due to the fact that there are two pairs of contact posts on the aerial switch that are oppositely disposed, as a reference to Fig. 12 in the SCIENTIFIC AMERICAN SUPPLEMENT, No. 1605, which is a side elevation of this device, will show.

When the various instruments have been placed in the positions shown they are ready to be connected with each other in accordance with the wiring diagrams given in Figs. 14 and 20 in the paper above cited. This done, connect the free terminal of the aerial wire or rat-tail to the aerial switch post indicated in Fig. 1, at *C*, and then attach the free end of the wire leading to the earthed plates to the post of the switch marked *D*. This completes the installation and the adjustment of the instruments individually and collectively is the next matter of importance.

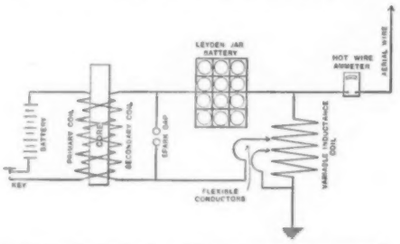


Fig. 3.—How the Hot Wire is Inserted in the Aerial Wire.

The sending apparatus comprise two distinct circuits, namely (1) the low-tension, or battery circuit, which includes the source of energy, the primary of the induction coil, the interrupter, and the Morse key, and (2) the high potential circuits, which include the secondary of the induction coil, the spark-gap, Leyden jars, and tuning inductance coil.

(*A*) The instruments included in the primary circuit should be adjusted first and these are mechanical rather than electrical. There are three adjustments necessary in order to make an independent interruptor work smoothly and efficiently; these are (*a*) the regulating screw making contact with the main circuit spring, (*b*) the regulating screw making contact with the shunt circuit spring, and (*c*) the sliding weight varying the period of vibration of the make-and-break springs.

The main contact adjusting screw, see Fig. 2, should be set so that the point of the platinum in its end and the surface of the platinum plate on the light spring just touch each other when the heavy spring carrying the armature and sliding weight are at rest. The shunt circuit adjusting screw is then made to come in contact with the platinum plate on the heavy spring. Now, on closing the primary circuit through the Morse key—the knife switch having previously been thrown into contact—the armature should be attracted by the polar projections of the magnet and the shunt and main circuit broken when the elasticity of the springs will throw them in the reverse direction, again completing the circuits, when the cycle of operations will be repeated.

If the interrupter does not start automatically on closing the circuit with the key the adjusting screws should be turned slightly to the right or left until it becomes self-starting. The current utilized determines within certain limits the period of vibration of the shunt circuit spring, and consequently by moving the sliding weight up and down on its supporting rod a point will soon be reached where the interrupter works most smoothly.

(*B*) As the condenser shunted around the make-and-break contacts of the interrupter has a fixed value, it requires no adjustment.

(*C*) The adjusting screw at the back of the Morse key should be screwed down so that when the compressional spring in front of the trunnions forces the contact points apart they should be separated a distance of about one-eighth of an inch. This completes the adjustments of the low-tension circuit.

(*a*) The adjustment of the instruments in the high-tension circuit is next in order and the spark-gap should be rendered operative first; since it is well known that if the spark-gap is too long, i.e., the balls of the spark-gap are too widely separated, the resistance will be so great that the discharge will not set up oscillating currents, but a unidirectional current, the spark-gap should be cut down to about one-half an inch or less, when the discharge should be white, snappy, and very thick. By carefully observing the color, sound, and size of the spark the operator will readily learn the striking distance that is the most effectual for the initial current used, and hence capable of bridging the longest distances.

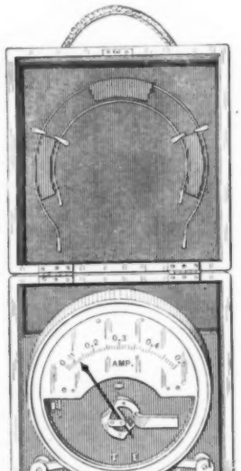


Fig. 4.—Hot Wire Ammeter.

(*b*) The number of Leyden jars best adapted to the requirements of the closed circuit in which it is included can be ascertained by empirical methods, that is, by actual testing. By referring to the original plans and specifications it will be observed that there are tweve jars connected in series. It is best to start with six jars coupled together and then increasing or diminishing the number until the maximum effect is produced; this effect is dependent not only on the capacity of the jars but on the initial energy employed, the length of the spark-gap, and the value of inductance that is used to counteract the capacity.

(*c*) The proper value of inductance is likewise best found by tuning the inductance coil to the capacity of the jars. To test their oscillating properties the Leyden jars and the tuning coil are connected with the spark-gap, forming a closed circuit, while the aerial wire and earthed wire are connected with the inductance coil through the aerial switch, forming an open circuit, and these circuits are associated by what is termed a "direct coupling."

(*d*) To tune the open to the closed circuit, so that their periods of oscillation will be the same, a hot-wire ammeter is introduced into the aerial wire as shown in Fig. 3. This form of ammeter is capable of measuring the current strength of electric oscillations of high frequency since it depends for its operation on the heating of a fine wire. The contraction and elongation of this wire under varying temperatures produced by the surging currents swings the needle, to which it is attached, over a scale.

Shunts are provided for these ammeters by the makers, and by using a short shunt one scale division equals 0.08 of an ampere, while the full scale gives a reading of four amperes. With a long shunt one scale

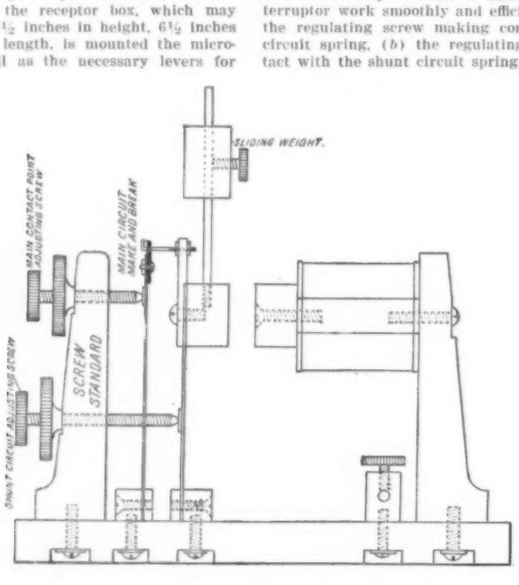


Fig. 2.—Side Elevation of Independent Interrupter.

* Specially prepared for SCIENTIFIC AMERICAN SUPPLEMENT. Previous articles by the same author on "The Design and Construction of a 100-Mile Wireless Telegraph Set" and "The Location and Erection of a 100-Mile Wireless Telegraph Station" appeared respectively in SCIENTIFIC AMERICAN SUPPLEMENTS 1605 and 1622.

division equals 0.04 of an ampere or two amperes at full size. This type of ammeter is shown in Fig. 4 and it must be used only in the open aerial wire circuit of the sending station.

(*e*) After the shortest shunt is put into the ammeter all is in readiness to tune the open aerial wire circuit with the closed circuit formed by the spark-gap, the condensers, and the inductance coil. The spring clips of the tuning coil are now adjusted so that only a quarter of one of the turns of the coil—the middle one—is brought into action.

The spring clips should be moved alternately in either direction, but together, until the reading of the ammeter is the highest. Then the number of Leyden jars should be varied and the clips on the coil should be moved farther apart until the ammeter gives the highest reading. A little experience will enable the operator to readily ascertain when the best values of inductance, capacity, and resistance have been reached, and consequently when the aerial wire is in tune with the closed circuit. In each test made the Morse key should be depressed long enough for the needle of the ammeter to come to rest.

A finer degree of tuning may now be obtained by placing a longer shunt in the ammeter and moving the spring clips on the inductance coil as before. If the adjustments are properly made the ammeter will indicate a still higher reading, for the tuning will have been more perfectly performed. After the highest degree of resonance has been obtained by tuning, the interruptor weight may be varied, and by so doing it is often possible to increase the amount of energy that is impressed on the aerial wire.

The circuits of the receptor comprise, like those of the transmitter, (1) a low-tension or local circuit, which includes the microphone detector, one or two dry cells, the potentiometer, and the telephone receiver, and (2) a high-tension circuit formed by the open and closed circuits, the latter also including the detector.

(*a*) The microphone should be adjusted first. The knife edges of the carbon must be very sharp and the needle free from grease. To remove all traces of grease and other untoward forms of matter that may have accumulated upon the polished surface of the needle, it is well to place it in a solution of boiling potash and handle it thereafter only with a pair of tweezers. After it is weighted and placed across the edges of the carbon strips it is ready to be tested and the local circuit tried out.

(*b*) The levers of the 10-ohm and 150-ohm rheostats are turned so that half of the resistance of each is thrown into circuit; the telephone receiver is adjusted to the head, and the operator listens attentively to ascertain if any sounds are emanating from it. By cutting down the resistance in the 150-ohm rheostat a point will soon be reached where the action of the current for the dry cells, as it flows across the high resistance offered by the imperfect contact between the edges of the carbon and the needle, can be easily heard; the resistance of the 150-ohm rheostat should be adjusted until the sounds are loudest. This done, the resistance of the 10-ohm rheostat should be varied when a value will be found where the sounds in the telephone receiver are considerably louder, and thus the detector is adjusted.

(*c*) When the microphone and local circuit is in working order, the open and closed circuits must be tuned to each other and the receptor syntonized to the transmitter. This is very difficult to accomplish satisfactorily without the aid of a *tuning device*, an instrument that will be described in detail, not only as to its construction but as to the methods of using it, in the succeeding paper.

Without the tuning device the only way to tune the receptor is by actually trying it out with the transmitter that is to be used in connection with it. The time of testing must be predetermined by the operators in charge of the stations, the letter to be used and the interval between successive transmissions. The method of procedure is like this: The operator at the transmitting station begins by sending the letter previously decided upon, say the letter H, four dots upspaced, according to the Morse and the Continental alphabetic codes, every minute for five minutes and then stops for a like interval. In the meantime the receiving operator will have had time to carefully adjust the tuning coil of his receptor so that the signals will come in as clear and loud as possible.

When this has been done, the operator sending the test letter should cut down the amount of the current used for energizing the induction coil by three-fourths to one-half the usual amount; the receiving operator is of course still constantly readjusting his tuning coil. When the tuning has been carried as far as possible the receptor circuits will not only be tuned in a measure, but the sending and receiving instruments will be syntonized, roughly, with each other.

To obtain a higher degree of resonance, both simple and sympathetic, a tuning device is absolutely essential.

Morrison, of Chicago, in 1891 attempted to improve the storage battery by modifying the pasted plate type. His cell has a remarkable construction, and appears to be giving very excellent results, the general design of the electrodes being in the direction of a solid network. Each electrode is built up of a number of thin pasted plates, placed horizontally, after the manner of the lamelles of the Planté plate. The cost of preparing and putting together the many little shelves of each electrode must be considerable, each small grid having to be first cast and pasted. All the thin pasted grids are then assembled, between each being placed a kind of sandwich composed of two pieces of prepared paper, and one piece of prepared grooved wood; a strip of lead is then burnt on to the ends of the shelves, and a big lug on the top. Each plate may be said to consist of a number of trays of active material exposed on both upper and lower sides to the action of the electrolyte, which can circulate through the openings of the grooved wood. There is electrolyte between each shelf, the electrodes being put very close together. The surface of active matter exposed in the electrolyte is thus very large in proportion to the sides of the electrode. A Morrison cell, rated at 450 ampere-hours, was tested in Chicago. The ampere-hour efficiency was found to be at a twenty-hour charge and discharge 90.8 per cent, at a five-and-one-half hour charge and a two-and-three-quarter-hour discharge seventy-four per cent, and the watt-hour efficiencies at the same rates were 83.66 per cent and seventy-four per cent, respectively. The cell was said to have been severely abused for some time, after which it was found to be practically unchanged.

AN HISTORICAL ACCOUNT OF THE EOLIPILE; AN ANCIENT STEAM GENERATOR.*

By S. J. Berard.

In contemplating the past history of man, we have reason to believe that from very early times the formation of steam and some of its results as in the boiling of water, and the cooking of food, have attracted attention. The familiar expression, "the pot boils over," was doubtless as evident to the primitve cook as it is to the modern. Female cooks of early times would naturally endeavor to prevent the escape of the savory contents of a vessel, by placing weight on the cover. It was not known then that a vessel of boiling fluid contained a spirit impatient of control, the vessel the generator, the cover the safety valve, forming practi-

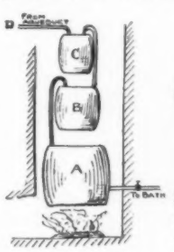


Fig. 1.

Fig. 2.

Fig. 3.

cally the prototype of the modern steam boiler. The preservation of the contents and the security of the attendant depended on letting the cover alone or not overloading it; hence it often happened that the confined vapor threw out the contents of the vessel with more or less violence. Then it was that the primitive cook perceived death as well as life in a boiling pot. It would be safe to assume that the primitive female cooks were the first experimenters on steam and the earliest witnesses of boiler explosions.

The observance of the force of expanding steam has attracted the attention of mechanicians in every age. We all recall the picture in our school reader of the boy Watt watching the cover of the tea kettle thrown open by the steam and noting the force with which it escaped from the spout. This anecdote goes back to a much older date, however.

There are intimations that the elastic force of steam was employed by several peoples of antiquity; but unfortunately the details of application have either never been recorded, or if they had, are lost. Some relics of its use as well as heated air, and other fluid such as alcohol and spirit, are to be found in the practical and experimental use of the eolipile, the deception practised by the heathen priesthood in the use of eolipilic idols, and the oracular or fighting eolipiles made in the form of men and animals.

Hero, of Alexandria, 130 B. C., is the first author who gives any account of the application of the vapor of water. His word cannot be quoted in the original, but in a little treatise by Stuart (1829), Hero expressly ascribes the sound produced by the statue of Memnon

Fig. 4.

Fig. 5.

to steam generated in the pedestal, and issuing from its mouth.

Now, by the researches of Champollion, who is the highest authority on the point, the Memnon of the Greeks is identified with Amenophis II., a prince of the seventeenth Egyptian dynasty, who reigned at Thebes sixteen hundred years before Christ. Here, then, we have an application of steam, if the surmise of Hero be true, before the date of the Exodus of the Israelites.

Cardan is the earliest modern author to mention any of the mechanical properties of steam. He appears to have known not only the expansive force of steam, but also the fact that a vacuum could be produced by its condensation; a fact so important in the action of the steam engine. He, first of the modern writers, gives a description of the eolipiles.

The simplest case of a machine for utilizing the expansive force of steam would naturally be evolved from the boiling pot, where, instead of the large opening in the top, it was so constructed that this opening was

Fig. 6.

Fig. 7.

contracted to a very minute hole. The action of such a machine when with its contents it was brought into contact with a very hot fire, would be similar to the blowing of the wind, and it became known as the eolipile or æolipile, from the Latin word Æolus (god of the winds) and *pila*, a ball, from the shape of the vessel, which resembled a ball. (See Figs. 2 and 3.)

One of the striking examples of the early use of the expansive force of steam was in the methods adopted by the Romans to elevate and discharge large volumes of water for heating the baths at Rome. From impressions found imbedded in the mortar and cement of ancient ruins, it is supposed that sets of caldrons were employed, each set consisting of three "closed" boilers placed directly one above the other, and connected by pipes, the manner of connection not being known, but supposed by Sir W. Gell to be by siphon. The lowest boiler was the largest and was placed directly over the furnace. Fig. 1 shows the supposed arrangement and the action is as follows: When part of the boiling water was drawn from boiler *A*, an equal quantity, already warmed, entered from boiler *B*, which at the same time derived a supply from boiler *C*, this latter being always kept filled by a pipe *D*, leading from an aqueduct. Remains of pipes, cocks, copper flues, etc., have been found in abundance, but details of the methods employed in elevating and distributing the liquid cannot be ascertained, so that the above description while reasonable may not be correct. From the number and magnitude of the hot baths of Rome, the operations of boiling and dispersing the water were conducted on a large scale. Single establishments accommodated at least two thousand persons with hot baths at the same time. We may call this a special type of eolipile, though the proper name for it is Hypocaustum.* It is practically the prototype of the modern kitchen boiler and water front, as practically the same method of drawing the water and automatically supplying more is there carried out.

From a remark by Vitruvius in his first book on architecture, we learn that steam eolipiles were in

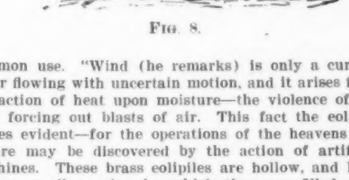


Fig. 8.

common use. "Wind (he remarks) is only a current of air flowing with uncertain motion, and it arises from the action of heat upon moisture—the violence of the heat forcing out blasts of air. This fact the eolipile makes evident—for the operations of the heavens and nature may be discovered by the action of artificial machines. These brass eolipiles are hollow, and have a very small opening by which they are filled with water and then placed on the fire: before they become hot they emit no effluvia, but as soon as the water begins to boil they send forth a vehement blast." The manner of filling them is very interesting. Since the size of the opening in most cases was no larger than the head of an ordinary pin, the usual method of filling would be a matter of some time and annoyance. To accomplish the result speedily and effectually, they were placed when empty on the fire, heated nearly red hot and then plunged into water. As the vessels cooled, the water took the place of the air previously driven out by the heat. They were commonly made of brass, iron, and strong copper.

From the few records and illustrations that have come down to us, they were used for many practical purposes as well as for amusement and experiment. Figs. 2 and 3 represent types that were used to increase the draft of chimneys, by forcing a strong current through them. Sir Hugh Platt (1594) published a figure and description of "a round ball of copper, or latton (brass), that blows the fyre verie strongile by the attenuation of water into ayre." Some were hung in the chimney directly over the fire "to cure smoky chimneys, for being hung over the fire, the blast arising from them carries the loitering smoke along with it." The Argand steam blower used in the firebox of boilers for creating more draft is really an improved

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* Yale Scientific Monthly. This article is the substance of a paper read by Mr. S. J. Berard before the Engineers' Club of New Haven.

* See Smith's Dictionary of Greek and Roman Antiquities.

type of eolipile. Some were used to turn spits upon which hung a joint of beef, the turning being accomplished by blowing against sails fastened to the spit. Fig. 4 represents a type for glass blowing. Fig. 5 is a type for fusing metals. *A*, in same figure, represents a portable eolipile to be held in the hand, and the blast applied to fixed objects.

Branca was probably the first inventor of the "steam turbine." He used an eolipile made in the form of the upper half of a man, the blast issuing from the mouth and impinging on buckets fastened to the circumference of a wheel, driving it very rapidly, and imparting motion to machinery for grinding corn, raising water, and for other practical purposes.

Fig. 6 represents Hero's eolipile, invented by him, and is the earliest known type of a machine driven by steam. It has been rightly called the first steam engine. Power could easily be transmitted by it, through *a*, band wheel fastened to one side of the ball. One of the columns supporting the hollow sphere is hollow, and conveys steam from the boiler below into the sphere. The escape of the vapor from the small tubes, by its reaction, imparts a revolving motion to the sphere.

Fig. 7 represents a light ball suspended in the air by the current issuing from the top of the eolipile. Balls dancing on jets of water or air are familiar to us as toys.

Music was produced by attaching wind instruments to the neck or orifice. A modern improved application is the delight of the small boy when the circus comes to town, namely, the steam calliope, which occupies an important place in the parade.

Revius mentions the use of eolipiles made of gold and silver, filled with scented water "to cause a pleasant temperature and to refresh the spirit and rejoice the heart of the sick as well as the healthy." Some were made in the form of birds and fowls. In an ancient church at Mentz is a silver crane, in the belly of which was put the fire, and which "gave out a sweet savour of perfumes by the open beake." Eolipiles have been used by philosophers to illustrate the nature of winds and meteors. They were molded in various forms of men and animals, the blast escaping from eyes, mouth, and other parts of the body. As late as the seventeenth century we are told that, "in order to make them more agreeable," they were commonly made in the form of a head with an open mouth. This was natural, since the god of the winds (for whom they were named) was represented as "a boy with blown cheeks emitting a strong blast of wind or air." It was supposed by the ancients that the air actually proceeded from the eolipile, but as steam could not support combustion, we must look to some other cause for its effect in this respect. We find it in the lateral communication of motion that takes place in fluids by which a current of air is made to follow the course of the steam that issues from the neck of the eolipile.

Blowing images were used in temples, their interior being charged with different liquids according to the circumstances. Liquids, as oil, turpentine, spirits of wine, etc., would cause streams and flashes of fire to shoot from parts of the body at the will of the priest. In the fifteenth or early part of the sixteenth century an eolipilic idol of ancient German origin was unearthed. It was made of a peculiar species of bronze three or four feet high in the form of a man, having a cavity capable of holding about seven gallons of liquid. Two holes for escape were used, one at the mouth and the other at the forehead. These holes for escape were stopped up with wooden plugs. The priests had secret methods of applying the fire.

According to Weber and other German writers, this idol was made to express various passions of the deity represented in order to extort offerings and sacrifices from deluded worshipers. When demands were not complied with, the ire of the god was expressed by sweat (steam) oozing from all parts of the body, and if they still remained obdurate his fury became terrible. Murmurs and bellowings were heard, thunder bolts shot out (the wooden plugs), emitting flashes and streams of fire from mouth and head, presently enveloping the body in clouds of smoke. It is easily seen how such a sight would strike terror to the hearts of the worshipers, and they, in their ignorance, would quickly comply with the demands. The priest had secret methods of applying the fire and means of increasing or diminishing the intensity of it dependent upon disposition of the worshipers. To protect themselves the priests would destroy or conceal the idols when discovery or betrayal was imminent, inventing new schemes to take their places. This is, no doubt, the reason why more relics of these superstitious times have not been found. What was once the means of deluding and mystifying mankind has now come to be his greatest benefactor.

From observations of early travelers in the East, we learn that eolipiles were employed in war. Carpini, in an account of his travels in A. D. 1286, describes eolipiles of human form (see Fig. 8), charged with inflammable liquid used in the battle between the Mongols and Prester John. The latter made a number of hollow figures of copper resembling men, charged with some combustible substance, "set upon horses, each having a man behind with bellows to stir up the fire. In giving battle, these mounted images were sent forward first, these men setting the fire to the combustible, blowing strongly with their bellows; and the Mongol men and horses were burnt with wild fire and the air was filled with smoke."

Supposing these eolipiles to be charged with alcohol or spirit of wine, modern experiments show that a jet of flame from one might have extended to a distance of 25 or 30 feet.

We can, from the foregoing, easily see how from the eolipile has evolved the steam boiler and the steam engine, and from these considerations it deserves a very prominent place in engineering annals. It is to be regretted that so little information of these most interesting relics has been handed down. Thomas Ewbank, in his interesting book entitled "Ewbank's Hydraulics," has collected a great deal of information on eolipiles and on ancient methods of raising water. It is profusely illustrated, showing examples of practically every known ancient device for raising water, and contains many descriptions of other primitive arts. The substance of this article, as well as the cuts accompanying, have been taken from the above book, and due acknowledgment is here made.

PHILIPPINE FORESTS.

ACCORDING to the report of Major Ahern, Chief of the Insular Forestry Bureau, the natural growth of the Philippine forests is computed to be 1,400,000,000 cubic feet—three times the yearly cut in the United States. At present fully ninety-nine per cent of the natural growth is going to waste, and the world is clamoring for the timbers. The ebonies, mahoganies, ironwoods, and all sorts of precious woods need only modern methods, a maximum of machinery and a minimum of handling, to make Monte Cristoes of the needed lumbermen. There are many millions of cubic feet of timber in the forests of the Philippines that should be cut in order to properly thin out the dense growth; for instance, where there are three or four trees growing on a space required for one, that one so freed would put on more good wood each year than the four together. The question as to whether three hundred or three thousand trees should remain on an acre is where the real value of scientific forestry comes in. Then too there are many more millions of feet which reach maturity and pass on to decay, never thrilling to the woodman's ax. There are, however, very few companies in the Philippines properly equipped to handle large logs, and without master mechanics, expert gang bosses, in fact all the skilled labor required, and without a full stock of the best supply material, it would be hazardous to move the large logs which must be cut and brought to market if the forests are to be properly exploited.

THE CHATTER OF THE TOOL.*

THE following are the general conclusions arrived at on the subject of chatter of the tool:

Chatter caused by the nature of the work:

A. Chatter is the most obscure and delicate of all problems facing the machinist, and in the case of castings and forgings of miscellaneous shapes probably no rules or formulæ can be devised which will accurately guide the machinist in taking the maximum cuts and speeds possible without producing chatter.

B. It is economical to use a steady rest in turning any piece of cylindrical work whose length is more than 12 times its diameter.

Chatter caused by the method of driving the work:

C. Too small lathe dogs or clamps or an imperfect bearing at the points at which the clamps are driven by face plate produce vibration.

Chatter caused by cutting tools:

D. To avoid chatter tools should have cutting edges with curved outlines and the radius of curvature of the cutting edge should be small in proportion as the work to be operated on is small. The reason for this is that the tendency of chatter is much greater when the chip is uniform in thickness throughout, and that tools with curved cutting edges produce chips which vary in thickness, while those with straight cutting edges produce chips uniform in thickness.

E. Chatter can be avoided, even in tools with straight cutting edges, by using two or more tools at the same time in the same machine.

F. The bottom of the tool should have a true, solid bearing on the tool support, which should extend forward almost directly beneath the cutting edge.

G. The body of the tool should be greater in depth than its width.

Chatter connected with the design of the machine:

Chatter caused by modifications in the machine may be classified as follows:

H. It is sometimes caused by badly made or fitted gears.

J. Shafts may be too small in diameter or too great in length.

K. Loose fits in the bearings and slides may occasion chatter.

L. In order to absorb vibrations caused by high speeds machine parts should be massive far beyond the metal required for strength.

The effect of chatter upon the cutting speed of the tool:

M. Chatter of the tool necessitates cutting speeds from 10 to 15 per cent slower than those taken without chatter, whether tools are run with or without water.

N. Higher cutting speed can be used with an intermittent cut than with a steady cut.

CHATTER AS PRODUCED OR MODIFIED BY THE TOOL.

This paper is chiefly concerned with chatter as it is produced or modified by the cutting tool itself. Some of the other causes for chatter, however, may be briefly referred to. These may be divided into five groups:

A. The design of the machine.

B. The nature and proportions of the work being operated upon.

C. The care and adjustment of the parts of the machine.

D. The method of setting the work in the machine or of driving it.

E. The shape of the cutting tools, manner in which they are set in the machine and the speeds at which they are run.

Causes A and B are outside the control of the machinist. Elements C, D, and E are or should be to a large extent under the control of the management of the shop.

Referring now to cause A, "The design of the machine," the chief elements causing chatter in the design of a machine are:

a. Gears which are set out of proper adjustment or the teeth of which are untrue. It should be noted that involute teeth will run smoothly whether their pitch diameters exactly coincide or not, whereas the epicycloidal teeth are almost sure to rattle unless their pitch lines are maintained in their exact proper relations one to the other.

b. Chatter is frequently caused through mounting the driving gears upon shafts which are either too small in diameter or too long. A large excess in the diameter of shafts beyond that required for strength is called for in order to avoid torsional deflection which produces chatter.

c. Lathe shafts and spindles must of course be very accurately and closely fitted in their bearings, and the caps adjusted so as to avoid all play.

d. For heavy work the lathe tailstocks should be fastened to the bedplates with bolts of very large diameter, and should be tightened down with long-handled wrenches.

e. The lathe bed itself should be exceedingly massive, and should contain far more metal than is required for strength or even to resist ordinary deflections, and the moving tool supports should also be heavy far beyond what is required for strength.

MASSIVE MACHINES NEEDED FOR HIGH SPEEDS.

Undoubtedly high cutting speeds tend far more than slow speeds toward producing minute and rapid vibrations in all parts of the machine, and these vibrations are best opposed and absorbed by having large masses of metal supporting the cutting tool and the head and tail stocks. It is largely for the purpose of avoiding vibration and chatter in machines that the high cutting speeds accompanying the modern high speed tools call for a redesigning of our machine tools. While it is true that in many cases a very great gain can be made by merely speeding up a machine orginally designed for slow-speed tools, this increase in speed almost invariably produces a corresponding increase in the vibration or chatter, and for absorbing this the lathes and machines of older design are in many cases too light throughout.

Cause C—namely, "The care and proper adjustment of the various parts of the machine," is almost entirely under the control of the shop management. It is of course evident that so far as the effect of chatter is concerned one of the most important causes can be eliminated from the shop by systematically looking after the careful adjustment of all of the working parts of the machine to see that the caps of the bearings are always so adjusted as to have no lost motion and yet not bind, and so that all gibs and wedges for taking up wear upon the various slides are kept adjusted to a snug fit. It is our experience, however, that the adjustment of the various parts of the machine should in no case be left to the machinist who runs his lathe, but that the adjustment and care of machines should be attended to systematically and at regular intervals by the management. In large shops a repair boss with one or two men can be profitably kept steadily occupied with this work. A tickler, however, should be used for reminding the repair boss each day of the adjustment of machines and the overhauling which should be attended to on that day.

CASES OF CHATTER CONTROLLED BY THE MACHINIST.

Cause D—namely, "The method of setting the work in the machine or of driving it," is in many cases capable of being directly under the control of the machinist.

a. One of the most frequent causes for chatter lies either in having too light or too springy clamps or lathe dogs fastened to the work for the purpose of driving it, or in having vibration at the point of contact between the lathe dog and the face plate of the lathe, or the driving bracket, which is clamped to it. In heavy work the clamps should be driven at two points on opposite sides of the face plate, and great care should be taken to insure a uniform bearing of the clamps at both of these driving points. Chatter through vibration at this point can frequently be stopped by inserting a piece of leather or thick lead between the clamps and the driving brackets on the face plate, which has the effect both of deadening the vibration and equalizing the pressure between the two outside diameters at which the clamp is driven by the face plate.

b. A dead center badly adjusted so as to be either too tight or too loose on the center of the work, or any lost motion in the tailstock of the lathe is such an evident source of chatter that it need not be dwelt upon.

THE SHAPE OF THE CUTTING TOOL IMPORTANT.

Cause E—namely, "The shape of the cutting tools, the manner in which they are set in the machine and the speeds at which they are run." In a previous part of this statement we have attempted to explain the effect of a uniform thickness of chip in causing chatter, and have indicated that the proper remedy for this

* From "The Art of Cutting Metals," read by Fred. W. Taylor before the American Society of Mechanical Engineers.

is to use a round-nosed tool, which is always accompanied by a chip of uneven thickness. We have elsewhere also referred to the desirability of having the body of tools deeper than their width in order to insure strength as well as to diminish the downward deflection of the tool, which frequently results in chatter, particularly when the tools are set with a considerable overhang beyond their bearing in the tool post.

We have also called attention to the great desirability of designing tools with their bottom surfaces extending out almost directly beneath the cutting edge, and of truing up the bottom surface of the tools, so as to have a good bearing directly beneath the nose of the tool on the tool support. If sufficient care is taken in the smith shop and the smith is supplied with a proper surface plate the tools can be dressed so as to be sufficiently true on their bottom surfaces for all ordinary lathe work.

It has been the necessity for avoidance of chatter which has influenced us greatly in the adoption of round-nosed tools as our standard. Tools with straight cutting edges, which remove chips uniform throughout in thickness can be run at very much higher cutting speeds than our standard round-nosed tools, but owing to the danger of chatter from these tools their use is greatly limited, in fact, almost restricted to those special cases in which chatter is least likely to occur. Attention should be called, however, to a method by which straight-edge tools have been used successfully for many years upon work with which there was a very marked tendency to chatter.

HOW STRAIGHT-EDGE TOOLS CAN BE USED SUCCESSFULLY.

While at the works of the Midvale Steel Company we superintended the design of a large lathe for rough turning gun tubes and long steel shafts, in which tools with long straight cutting edges were used without chatter, and yet at the high speeds corresponding to the thin chips which accompany this type of tool. This lathe was designed with saddle and tool posts of special construction, so that two independently adjustable tool supports were mounted on the front side of the lathe and one on the back side. In each of these slides a heavy straight-edge tool was clamped. The three tools were then adjusted so that they all three removed layers of metal of about equal thickness from the forging, and although the tendency toward chatter, owing to the uniform thickness of the chip, was doubtless as great with these straight-edge tools as with any others, the period of maximum or of minimum pressure for all three tools never corresponded or synchronized, so that when one tool was under maximum pressure one of the others was likely to be under minimum pressure. For this reason the total pressure of the chips on all three tools remained approximately uniform and chatter from this cause was avoided.

THE RULE REGARDING A STEADY REST.

Cause B—namely, "The nature and proportions of the work being operated upon."

In assigning daily tasks to each machinist with the help of our slide rules, the element which still continues to give the greatest trouble to the men who write out these instructions is deciding just how heavy a cut can be taken on the lighter and less rigid classes of work without causing chatter. This branch of the art of cutting metals has received less careful and scientific study than perhaps any other. While the element is one which must always remain more or less under the domain of "rule of thumb," since the causes which produce chatter, particularly in castings of irregular shapes, are so many and complicated as to render improbable their successful reduction to general laws or formulæ, undoubtedly much can be done toward attaining a more exact knowledge of this subject, and experiments in this line present a most important field of investigation.

The following rule (belonging to the order of "rule of thumb"), which has been adopted by us after much careful and systematic observation extends over work both large and small, and covers a wide range:

It is economical to use a steady rest in turning any piece of metal whose length is more than twelve times its diameter.

When the length of a piece becomes greater than twelve times its diameter it is necessary to reduce the size of the cut to such an extent that more time will be lost through being obliged to use a light cut than is required to properly adjust a steady rest for supporting the piece.

There is one cause for chatter which would seem to be impossible to foresee and to guard against in advance—i.e., chatter which is produced by a combination of two or more of the several elements likely to cause chatter. If, for instance, the natural periods for vibration in the tool and in the work or in any of the parts of the lathe and the work happen to coincide or synchronize, then chatter is almost sure to follow, and the only remedy for this form of chatter seems to lie in a complete change of cutting conditions, a change, for instance, to a coarser feed, with an accompanying slower cutting speed, or *vice versa*. Unfortunately for economy higher speeds rather than slow speeds tend to produce this type of chatter, and the remedy therefore generally involves a slower cutting speed.

THE EFFECT OF CHATTER UPON THE CUTTING SPEED.

A tool which chatters to any great extent must be run at a rather slower cutting speed than a tool which runs free from chatter, as will be seen by the following carefully tried experiment:

A forging 14 feet long, 4⅝ inches in diameter, made out of exceedingly hard steel, which was especially hammer-hardened and uniform, was placed in the lathe and standard cuts 3-16-inch depth and 1-16-inch feed (with our standard round-nosed tool ⅞-inch) were taken upon it in such a way that they first ran smoothly without chattering; other cuts were then taken in such a position on the forging that the tool chattered badly throughout its cut. This was accomplished by using a steady rest in one case, so as to prevent chatter, and in the other case running without the steady rest. All of the tools had been carefully standardized before starting the experiments, and proved uniform and capable of running at maximum cutting speeds. The forging had also been proved uniform, and its standard cutting speed had been shown to be between 15½ and 16 feet per minute.

In the accompanying table are given the details of the cutting speeds obtained with and without chatter. In one of these experiments the tool was run without water and in the other the tool was cooled through the use of a heavy stream of water. An examination of the results of this experiment indicates in general that chatter causes a reduction in cutting speed of from 10 to 15 per cent, whether tools are run without water or with a heavy stream of water to cool them.

Cutting With and Without Chatter.

Test No.	Mark on tool.	Cutting speed. Ft. In.	Duration of cut. Min.	Condition of tool at end of run.	Chattered or not.
		NO WATER ON THE TOOL.			
124 b	U_8	15	20	Good.	No chatter.
125 b	U_8	17 6	14½	Ruined.	No chatter.
126 b	U_8	15	4¾	Ruined.	Chattered badly.
127 b	U_8	15	9¾	Ruined.	Chattered badly.
		WATER ON THE TOOL.			
128 b	U_{10}	19	5½	Ruined.	Chattered badly.
129 b	U_{10}	19	20	Fair.	No chatter.

Experiment No. 125b was made for the purpose of again showing conclusively that both the tool and the forging had been properly standardized. It will be noted that this tool, free from chatter, broke down in 14½ minutes at a cutting speed of 17 feet 6 inches, whereas the tool just above it ran all right at 15 feet for 20 minutes, showing that both the forging and tools had been properly standardized.

Accurate experiments on the chatter of the tool are difficult to make because the comparatively small diameter of work which is needed to insure chatter calls for an extremely hard piece of metal (i.e., slow cutting speeds) in order to make the runs, which must last for 20 minutes, extend through a sufficiently short distance over the length of the forging, so that the tools shall not be in danger of chattering. It was for this reason that we were obliged to make the above forging out of extremely hard metal.

HIGHER CUTTING SPEED WITH AN INTERMITTENT CUT.

An intermittent cut, however, has a very different effect upon cutting speed from that produced by chatter. We have observed in a large number of cases that when a tool is used in cutting steel with a heavy stream of water on it (and this is the proper method of cutting steel of all qualities), a rather higher cutting speed can be used with an intermittent cut than with a steady one. The reason for this is that during that portion of the time when the tool is not cutting the water runs directly on those portions of the lip surface and cutting edge of the tool which do the work, and for this reason the tool is more effectively cooled with intermittent work than with steady work. As an example of intermittent work, the writer would cite:

a. Cutting the outside diameter of a steel gear wheel casting, in which case the tool is only one-half its time under cut.

b. Or turning small pieces of metal which are greatly eccentric.

c. Or, for example, all planer and shaper work which is not too long.

It would seem from a theoretical standpoint that a tool would be greatly damaged (and therefore a slow cutting speed would be called for) by the constant series of blows which its cutting edge receives through intermittent work. It will be remembered, however, that in planer work (and this class of intermittent work comes to the direct attention of every machinist) the tool is more frequently injured while dragging backward on the reverse stroke of the planer than it is while cutting, and it is very seldom that a tool is damaged as it starts to cut on its forward stroke. In all cases, however, where the tool deflects very greatly, when it starts its cut on intermittent work slower speeds are called for than would be required for steady work.

The above remarks on intermittent work do not of course apply to cast iron with a hard scale or the surface of which is gritty. It is evident that in all such cases, owing to the abrasive action of the sand or scale on the tool, intermittent work is much more severe upon the tool than a steady cut.

GEAR-CUTTING MACHINES.

TEN years ago, when the bicycle was at the height of its popularity, it stimulated an enormous trade in a certain class of machine tools. Had the bicycle not come, the mechanical engineer would likely enough have continued to the present day with tools of the type used by his grandfather. But it gave the machine-tool maker an opportunity which he was not slow to take. There was a rush for certain classes of machines, and they could not be made fast enough to meet the demand for them. The cycle industry, after "booming," settled down to a steady pace. Then comes the motor-car, and again the machine-tool maker rises to the occasion; made the very tools that are wanted, and—in spite of what he says himself—reaps his reward.

No motor car is without gearing of some kind, and no gearing of any kind works well if it is not well made. At first—the complaint has not yet been wholly removed—we had to tolerate a gear-box that made a noise like a factory, but knowledge, skill, and, above all, excellent machines for the rapid and cheap production of accurate toothed wheels has changed, or is changing all that, and we now expect a box of gears to work so silently that it can only be heard when the ear is placed pretty close to it. For this perfection the motor car user has to thank the machine-tool maker, who has exercised considerable ingenuity in providing a variety of machines that will produce almost perfect teeth on plain, bevel, helical, or worm wheels with a speed and precision that are quite remarkable.

If two sets of gears are to run smoothly together, the teeth must have certain specified forms. By a long way the most widely used tooth nowadays is the involute. It is easy to draw, and easy to make, and a small error in the distance between two geared wheels does not affect the smoothness of the running. But whatever form of tooth is employed, certain essentials must be met if good workmanship and satisfactory results are sought. First, the pitch must be absolutely accurate. Secondly, the shape of the tooth must be correct, and must be precisely the same on both sides, and, finally, the tooth must be placed in its correct position on the pitch-line. The last is a matter of adjustment, the first depends on the accuracy of the machine tool, the second depends upon the shape of a cutter in milling, hobbing, and some shaping machines, and upon a former or model in other machines, while in one—the Robey-Smith—it is produced by a very elegant geometrical device. These remarks apply equally to all kinds of gear, but bevel and miter wheels are complicated by the necessary taper form of the tooth. The beautiful devices which have been invented to produce a correct bevel tooth form a fascinating study.

The oldest and most obvious way of producing the tooth of a spur wheel is to mount the blank in a slotting or shaping machine, and use a tool formed precisely to the shape of the space between any two teeth. The next most obvious plan is to replace a reciprocating tool by a revolving one—that is, a milling cutter. If the milling cutter is properly made, there is probably no more accurate manner of producing a spur wheel than this. When we leave machines of these two types we pass from the obvious to the ingenious, and we find clever machines for hobbing spur wheels, or for producing them by the use of a highly specialized form of cutter, as on the Fellows machine. All the machines of this type depend upon an invaluable characteristic of the involute tooth, about which a few words must be said. This characteristic is that an involute rack tooth has straight sides. The flank of an involute tooth is struck with a radius equal to half the radius of the pitch circle. A rack may, of course, be regarded as a wheel of infinitely large radius, and, since half an infinitely long thing is still infinitely long, the radius for the flank is of infinite length, and the flank is, therefore, straight. Having this peculiarity, it will be seen that an involute rack will gear with all involute wheels, of no matter what diameter, having the same pitch. Could anything be better from the machinist's point of view? Let him convert his rack into a cutting tool, and harmonizing its slotting motion with the correct speed of rotation of the blank, with one cutter he can produce a whole host of gears of different diameters. Moreover, since all these gears will gear with the same rack, they will all gear together. Really, when we consider this obliging nature of the involute tooth we cannot but feel that it is doing its best to make things easy for the machine-tool maker.

In the gear-hobbing machine, in place of a slotting motion, we have a rotary and continuous action, but the principle is precisely the same. The hob has flat-sided teeth, arranged in a spiral of the proper pitch, and it is tilted longitudinally when cutting straight teeth to the same angle as its pitch—that is to say, till the teeth on the cutting side of the hob appear to travel straight across the face of the blank. In use the blank, of course, must be given the proper speed of rotation to harmonize with the hob. An obvious development of this idea is to slew the hob further round still and cut skew, spiral, or helical gears.

In the Fellows machine, instead of using the rack itself for the purpose of developing the tooth, an intermediary is employed. A cutter, which closely resembles the wheel itself, is made from the rack, and is used to cut the teeth in the blank by a slotting motion.

When we come to bevel gear-cutters we have, as already mentioned, to meet another set of conditions. The tooth is tapered in two directions, and it is clear, on a moment's consideration, that a milling cutter cannot produce a correct shape at more than one place in each tooth. In certain cases the error may be very small, and by dividing it cunningly may be rendered almost negligible, and when they are short, bevel teeth may be milled, but, at the best, only an approximately accurate tooth can be produced. Other means have therefore to be sought, and, though a rotary cutter may be employed, as in the Warren machine, a shaping or planing action is in more general use. In some cases, as in the Oerlikon machine, and some forms of the Gleason, a former is used to guide the tool in the right path, while in other machines, such as the Bil-

gram, the Nardin, and the automatic Gleason, the principle of the rack already discussed with regard to straight teeth is employed. But in cutting bevel gears it is not sufficient for the blank to revolve as in spur-wheel cutting. It must have a rolling motion of the same kind that a cone lying on its side and pushed along a table has, or as the wheel would have if it were pushed freely over the wheel with which it pairs correctly. It is in the means employed to obtain this rolling motion that the most interesting features of these machines are found.

The foregoing comprises, in the main, the introductory remarks of a supplement issued by The Engineer (London), wherein are discussed at considerable length the features of some twenty-five representative American, English, and continental machines of this nature.

EXCAVATING THE FOUNDATIONS FOR THE TUNNEL UPON THE BED OF THE DIVERTED STREAM.

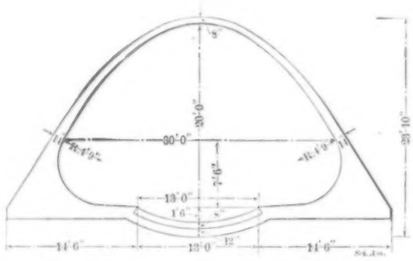
A NOVEL ENGINEERING ACHIEVEMENT—BURYING A RIVER TO A DEPTH OF 120 FEET.

By the English Correspondent of SCIENTIFIC AMERICAN.

AN engineering work novel in character, possessing many interesting and unusual features, and of considerable magnitude, is now in progress in the north of England; it is being undertaken at the initiative of the municipal authorities of Newcastle-on-Tyne. A flourishing and popular suburb has sprung up at Heaton, separated from the city by an extensive valley, which is a continuation of the beautiful Jesmond Dene. Intercommunication between the two points at the present time is very insufficient, owing to the fact that only one bridge is available for pedestrian and vehicular traffic across this ravine between the city and the suburb. The valley itself varies in width from 300 feet to 1,100 feet, while at the bottom, 120 feet below the level of the respective banks, flows the stream known as the Ouseburn. In order to remedy the shortcomings regarding the sadly-needed intercommunication, it has been decided completely to fill the valley for the whole of the distance between Newcastle and Heaton.

As far back as 1889 the question of providing better communication between the city and the suburb was discussed by the Newcastle municipal authorities, and a viaduct across the valley, more conveniently situated than that at present in use, and estimated to cost some $500,000, was suggested. But the scheme was indefinitely shelved. Eleven years later, however, a project for the filling of the ravine was proposed, but the presence of the river offered several difficulties, and for five years nothing further was done in the matter. However, the remarkable success that in the meantime has attended the use of ferro-concrete showed a means of surmounting the problem in connection with the Ouseburn stream, and Mr. C. R. S. Kirkpatrick, the engineer to the city council, prepared designs for a ferro-concrete tunnel to carry the waterway, which would itself be buried. This project was as against the suggested viaduct, although the cost incurred will be somewhat greater, aggregating approximately $803,830 in the construction of the tunnel, acquisition of the ground comprising the valley, and the laying out of roads. However, considerable revenue will accrue from the charges levied for the permission to discharge material into the valley for filling purposes, while ultimately a large area of land for building will be available.

The total length of the conduit through this valley will be 2,060 feet, the course of the river through the valley being roughly in the form of an S. In order to be able to cope with heavy flood waters or any other unforeseen exigencies, the tunnel surpasses any other work of this class that has been carried out, both in regard to its nature and proportions. Several systems of construction were investigated, and finally it was decided to adopt the Hennebique ferro-concrete system, and this section of the undertaking is now being actively carried out by Mr. W. T. Weir, the well-known contractor of Howdon-on-Tyne. The tunnel, as may be seen from the accompanying sectional diagram, is of parabolic form with a maximum width of 32 feet, internal measurement, and is 23 feet in height, with a cross-sectional area of 477 square feet. Some idea of the weight to which the crown of the tunnel will be subjected may be gathered from the fact that there will be a filling some 100 feet in depth above, and finally the buildings that will be erected upon the leveled area. From an engineering point of view, the comparatively slender thickness of the ferro-concrete at the crown, which is only 8 inches, will appear somewhat startling, when the great thickness of brick and masonry structures for such works is taken into consideration; but as a matter of fact this thickness is entirely adequate for the purpose, owing to the circumstance that in reinforced concrete erections the steel employed takes those stresses which would prove fatal to a solid masonry structure, in which mere mass is not only very often of comparatively little use, but may prove absolutely disadvantageous.



CROSS-SECTION OF THE FERRO-CONCRETE CULVERT.

The work was commenced in February last, the initiatory preparations involving the temporary diversion of the stream to permit the foundations of the tunnel to be laid, together with means of dealing with any sudden charges of flood water, since after a heavy rainfall this stream is converted into a raging torrent. The stream was diverted from its bed into the sewer, while a temporary dam and timber troughing were erected for coping with storm water. When the bed of the stream was laid bare steam excavators were set to work, leveling the ground for the foundations of the culvert. The ballast was dumped into trucks which were hoisted bodily onto a temporary railroad that was laid down on either side of the valley, and which were then hauled by steam winches to the road levels above, the contents shot into other waiting wagons, which were hauled along railroads and dumped at the required points.

At the commencement of operations difficulties were experienced at the site of the outlet of the tunnel. Here an area of soft earth was found, and it was found necessary to carry out excavations to a depth of 25 feet more than was anticipated. The resulting cavity was then filled with concrete. At another point some disused colliery workings were met, and these also had to be filled with concrete. Altogether, for the purposes of the foundations some 30,000 cubic yards of earth will have to be excavated, the removed ballast being utilized in connection with the work of filling the valley. At the present time some 500 feet of ferro-concrete work have been completed.

The material employed for the preparation of the concrete is broken ballast from the Tyne, crushed so as to pass through a mesh of ¾ inch, the proportion being 5 to 1. The steelwork utilized consists of rods varying in diameter from 5-16 inch to $1\frac{1}{2}$ inches, the tensile strength at rupture varying from 28 to 32 tons. The greatest distance between the bars when laid is 12 inches. A total of 850 tons of steel and 17,000 cubic yards of concrete will be utilized in the 2,600 feet of tunneling. It is anticipated that the culvert will not be completed before the end of the year 1907, but filling the valley has now commenced upon the section of the tunnel which is already completed. Altogether, some 2,750,000 cubic yards of ballast will be required to fill in the depression. In the course of this task several houses and other works will be demolished and buried, but the tenants will not be required to vacate until the ground is actually required, so that the municipal authorities will derive revenue from the rents for the land up to the moment they are needed, thereby reducing somewhat the cost of the undertaking. Owing to the immense quantities of ballast that it will be necessary to dump into the valley, it will be some years before the latter will be filled to the level of the upper roads on either side, and the ground rendered available for building purposes. The work of construction is being supervised by Mr. J. C. Midgley, of the Newcastle-on-Tyne municipal engineering department, to whose courtesy we are indebted for the accompanying illustrations showing the work in progress. The total cost of the tunnel itself will be approximately $160,000.

WOODEN FORMS AND STEEL REINFORCEMENT FOR THE CULVERT NEAR THE OUTLET.

A NOVEL ENGINEERING ACHIEVEMENT—BURYING A RIVER TO A DEPTH OF 120 FEET.

EARLY VICISSITUDES OF ENGINEERING.*

By W. H. DUGDALE, M.Inst.C.E.

IN speaking of engineering, I am using the term in its generic sense, regarding shipbuilding as one of its important branches. Shipbuilding *per se*, I admit, is much older than engineering in the ordinary acceptance of the term, and its origin was probably due to the accidental discovery that a log would float and also carry weight. The gradual evolution of shipbuilding was an exceedingly slow process, and since the art of reading hieroglyphic inscriptions was discovered, namely, about 1820, and the tombs of Egypt have been systematically explored, we have discovered rude representations of boats probably of Libyan origin, dating between 5000 and 6000 B. C. The most ancient mention of any ship is in the reign of Betou, eighth king of Egypt after Mena, and head of the second dynasty; and the late Mariette Pasha, a renowned Egyptologist,

* Abstract of Presidential Address to the Northeast Coast Institution of Engineers and Shipbuilders, England.

fixed the date at 4235 B. C. I am not going to take up your time giving you a chronological list of ships from this period to the vessels used by Columbus at the end of the fifteenth century, nor yet to describe them, as they are all familiar to you. I only mention the matter incidentally to show what an exceedingly slow and tentative evolution took place in shipbuilding during about sixty-seven centuries, and although during the next three centuries—that is, to the end of the eighteenth century—the evolution was more rapid, it was during the nineteenth century that the great strides were made.

Mechanical appliances also must have been adopted at a very early period; otherwise the huge blocks of granite quarried at Assouan, many of them varying from 18 to 60 tons weight, could not have been transferred and erected at the pyramids, etc. To what extent these appliances were based upon actual scientific knowledge it is difficult to say, but in any case engineering may reasonably lay claim to being one of the learned professions from about 400 B. C., when Archytas, the reputed inventor of the screw, who died about 394 B. C., and Eudoxus, who died 352 B. C., both of whom were geometricians and philosophers, turned their thoughts to mechanics; but Plato inveighed against them with great indignation as corrupting and debasing the excellence of geometry, and making it descend from the intellectual to the practical; so that for some time applied mechanics was despised by the philosophers, and considered as simply a branch of the military art. The ancient philosophers esteemed it an essential part of learning to conceal their knowledge from the uninitiated, as they considered its dignity was lessened, and even went so far as to regard the introduction of mechanical subjects into the region of philosophy as a degradation of a noble profession. This prejudice was shared by Archimedes, the most learned geometrician of his time, and who died B. C. 212, but his friend and relative, Hiero, King of Syracuse, had sufficient influence over him to persuade him to descend from his lofty speculations and render his reasonings in some degree more evident by connecting them experimentally with things in daily use, with the result that he rendered great mechanical assistance during the siege of Syracuse; and although undoubtedly mechanical appliances were in use long before the time of Archimedes, yet he will always be of interest to us as one of the earliest exponents of applied science, and his name, of course, will be always familiar as the inventor of the Archimedean screw, which, by the by, he invented to clear the water out of the hold of a large vessel built by King Hiero and sent with a cargo of grain to Alexandria.

During the reign of the Grecian kings in Egypt, arts and sciences attained a high degree of excellence, and the court of Alexandria was resorted to as a school of philosophy; mechanics and the kindred sciences were held in great esteem, and eminence in their acquirement becoming a pathway to personal honor, the boundaries of knowledge were extended through the exertions of its professors to attract the countenance of their illustrious patrons. One of the most distinguished men of genius who enjoyed the patronage of these munificent princes was Hero, the son of a Greek who had settled in Alexandria. At an early age he displayed a strong bent toward mechanical pursuits and devoted his life to their study. He is the first of whom we have any definite record as having experimented upon the action of heat on air and water, and wrote several problems upon it. He describes three modes of using steam directly as a mechanical power, namely, to raise water by its elasticity, to elevate a weight by its expansive power, and to produce a rotary motion by its action upon the atmosphere. It is curious that so ingenious a people as the Greeks should not have been led by those direct experiments to a practical application of the agent so exquisitely molded by Hero into a mechanical power. The centuries of turbulence which succeeded were so unfavorable to genius

THE COMPLETED OUTLET OF THE CULVERT.

of every kind that very little progress was made in the development of mechanical invention; so that the application of heat to water did not attract much, if any, attention, until toward the end of the sixteenth century, and one of the first suggestions of any practical application of steam was by Branca, an Italian architect and engineer, in 1629, who illustrated a jet of steam impinging upon the vanes of a wheel and producing rotary motion, which was transmitted to other wheels moving stamps over mortars.

The first Englishman who devoted himself with any degree of enthusiasm to mechanical arts was the Marquis of Worcester, who died in 1667. One of his problems is noteworthy, as it gives us strong ground for the supposition that he was acquainted with some mode of elevating a piston by steam. Almost in a state of destitution, oppressed with debt and without resources, he applied to Parliament for assistance to insure a fair trial of his inventions, and in 1663 he succeeded in procuring an act of Parliament enabling him and his heirs for ninety years to receive the sole benefit, profit and advantage resulting from his invention (namely, a "water-commanding machine"), but one-tenth part of all profit which might be realized was to be appropriated without abatement to Charles II. and his successors. After the death of the Marquis, his wife, who seems to have been a congenial spirit and shared her husband's enthusiasm, continued her exertions to introduce this "water-commanding machine," but the zeal with which she prosecuted her scheme was considered unbecoming her sex and derogatory to her quality; therefore a priest, who had some influence, was selected to expostulate with her. The history of engineering from the middle of the seventeenth century and the names of those who, in England and on the Continent, experimentally and otherwise have contributed so much to bring about its present perfection, are familiar to you all, but I have spoken somewhat at length regarding Lord Worcester to show that, although the idea of steam as a mechanical agent existed at the time of Hero, very little progress had been made by the middle of the seventeenth century; and even then, as of old, the development and application of arts and sciences were largely influenced by court patronage and priestly interference, and although individuals from time to time had been interested in scientific research and experiment, the facilities for acquiring or diffusing knowledge were very limited; the art of printing was practically confined to London.

ERECTING THE CENTERING FOR THE CONCRETE CULVERT.

A NOVEL ENGINEERING ACHIEVEMENT—BURYING A RIVER TO A DEPTH OF 120 FEET.

PRACTICAL HINTS FOR CONCRETE CONSTRUCTORS.

IN one of its issues Engineering News published an article under this title, by W. J. Douglas, Engineer of Bridges for the District of Columbia, which is by far the most complete treatment of the subject that has come to our notice. This contribution, of something like ten thousand words, is so concisely written that it is extremely difficult to indicate here more than an outline of its contents, the multitude of facts presented in such small compass creating in the reader an impression that the article itself is an abstract of a work of no inconsiderable size.

Mr. Douglas attributes our lack of success in hitherto obtaining as good results in finished concrete work as the French to a number of causes, namely: want of experience, inferiority of workmanship, carelessness in mixing and placing, and a neglect of the proper study of designs. Great improvement, however, is now being manifested in these particulars, the most important general problem now being that of overcoming efflorescence.

In the matter of design, the author states that, except for very flat arches, the common theory, intelligently applied, will yield as good results as those obtained from the elastic theory; but that the designer should by all means be acquainted with the latter.

In the absence of first-class inspection, concrete (1:2:3) in compression should not be stressed higher than 300 pounds per square inch, nor more than 400 pounds, with such overseeing. A design should be chosen, when possible, which gives but little tension or shear. The parabola, catenary, and circle are the best curves for concrete arches and require but little reinforcement. Very flat arches act more like beams than arches.

When in doubt, reinforcement is always advisable, and in beams absolutely necessary, unless absurd depths are employed. Bars having a mechanical bond are recommended for a number of very practical reasons.

Much money can be saved by using leaner mixtures in foundation and mass work than is common in practice; this, however, requires better mixing and supervision than is usually had.

In regard to the esthetic appearance of concrete structures, much of the monotonous uniformity of color can be done away with by using sands or crushed stones of different hues—this in preference to the use of artificial coloring matter, which, in addition to its lack of permanence, often weakens the cement.

Marble details should be avoided in ornamental work. "Don't try to imitate stonework. . . . Remember that concrete is a new material with new virtues and vices. Forms are permissible with it that were impossible for the Greeks and Romans, and the older forms may not be possible in concrete. If the engineering conditions warrant a lintel 75 feet long, don't make it look like an arch. Don't dwarf your structure with excessive paneling, which suggests parlor furniture."

On large face-work, where air tools may be used, the surfaces may be bush-hammered or crandaled for from one cent to three cents per square foot.

Large masses having cross-sections of over, say, 200 square feet, will frequently "hair-crack" when setting. While not seriously detrimental, this may be avoided on fronts or other visible surfaces by the use of a light reinforcing of expanded metal, wire-mesh, or light rods about 4 inches from the face.

In the construction of work provision should be made for drainage of water, no pockets, for instance, being allowed at the back of retaining walls. Waterproofing paper should not be applied to vertical walls for the reason that it frequently bulges, leaving pockets which hold water.

Expansion should be provided for in retaining walls by the use of construction joints at about every 50 feet.

In designing it is well to assume that unskilled mechanics will perform the work.

"Remember that concrete in setting shrinks and that there will always be a very small crack existing between abutting sections of work executed at different times. Concrete which sets up under a head shrinks less. Concrete rich in cement shrinks more. Concrete made with coarse sand shrinks less than that made with fine sand."

Specifications should not be finally passed upon until drawings have been finished and approved. Only materials easy to obtain in the market should be specified, and methods should not be adopted in which the engineer has had no experience. Old specifications should not be copied blindly, nor should clauses which it is not intended to enforce be included. No specifications at all are better than bad ones.

As to engineering supervision he suggests, if it is necessary to employ inexperienced men, that carpenters should preferably be chosen. In the selection of

a concrete mixer, a batch mixer that has been in successful operation for a number of years will give the best results. Materials are considered, their advantages and disadvantages discussed, and a number of tests given. In blocks and reinforced work soupy concrete wetter than concrete for mass work should be used. Blocks should be cast with the most important face down, all others showing faces being cast vertically. Concrete should not be tool-dressed until 30 days old (preferably 60 days).

Frozen materials should not be used. When concreting in winter, the stone and sand should be heated, preferably with a coil of steam pipe; and with care the concrete may be easily placed at a temperature of 60 deg. F. This work, however, should not be attempted much below 32 deg. F.

NEW INCANDESCENT ELECTRIC LAMPS.*—III.

COMPARATIVE EFFICIENCY OF THE DIFFERENT SYSTEMS OF ILLUMINATION.

THE great improvements in the technics of illumination which has been brought about during the last thirty years comprise not only an increase in power of light, but also a cheapening of the illuminant and decreased consumption of energy. In deducing the value of a system of lighting from the cheapness of the unit of illumination produced, the public are often led quite astray. In the competition between the various systems of lighting, tables are often drawn up by the manufacturers compiled from the scientific results of well-known men. These tables purport to show the value of some particular form of lamp, but they fail to indicate the conditions under which the results were obtained, whether the reflectors were used or not, or whether the results are calculated for the whole sphere or only the hemisphere of illumination. A true comparison is only possible when all the conditions and requirements are taken into account. For instance, it is not possible simply to compare a certain source of light in regard to the illumination of a single place in a closed room with a second which serves to illuminate a large room or a hall; in many cases also in the application of a source of light the color of the light must also be taken into account. It must also be noted that the technical efficiency of a single source of light does not give us at the same time information about the price or the cost of working. Electricity, for instance, is a form of energy which, in the present state of industry, costs much more than the equivalent amount of energy would cost in the form of paraffin or illuminating gas; it is, without doubt, a luxurious form of energy. This, however, is a purely external consideration, which may and does alter from day to day.

After the incandescent petroleum light, the incandescent gas light is the cheapest light, and, in the struggle between gas and electricity, it has succeeded, in spite of the most difficult circumstances imaginable. To the prophecies which have not been fulfilled belongs that which stated that gas light would soon be pushed into the background by the electric light. The two competitors still compete courageously with one another, and to this struggle we are indebted for the incentive to progress. The gas consumption in the last decade shows that the gas engineer need not despair. In the year 1859, 1,400 million cubic feet of gas were burned, while to-day the consumption amounts to more than 28,250 million cubic feet.

In spite of its expensive working, the incandescent electric light has found an extraordinary dissemination, a sign that a great demand exists for a small electric lamp suitable for the illumination of interiors. As the gas lighting technicians, on the one hand, have attempted to replace the large electric lights by intensified gas lamps and the like, to which the electrotechnicians have replied by the creation of the flame arc lamp, so, on the other hand, electro-technicians and chemists, even the discoverer of the incandescent gas light himself, as we have already related, have endeavored for years to produce an economical incandescent electric lamp.

Of all the new incandescent electric lamps brought on to the market up to the present, none have been able to supplant the carbon filament lamp, in spite of its high consumption of current. The Nernst lamp, on which the greatest hopes have been placed, because it only required about half as much current, tolerated high voltages, and could be easily connected up, is handicapped on account of the necessary preliminary heating and resistance coil for the glow rod, which makes it dear to manufacture.

The osmium lamp, the improvement of which is still being pushed forward zealously, as is the case with the Nernst lamp, has also the disadvantage of a high cost of production, and, moreover, will only work with low voltages. The highest so far used is only 47 volts. The lamps must, therefore, be arranged in series for the ordinary voltage supplied. This means always burning several at a time, or else special devices must be used to divide the voltage. It is possible that the voltage may now be raised so that two lamps can be burnt in series, but this advantage can only be attained by an increased cost of production. The consumption of current amounts to 1.5 watts per candle, which is, therefore, about half that of an incandescent carbon lamp; the life is about the same as that of a carbon lamp, perhaps a little less. Compared with the Nernst lamp, however, it has the disadvantage that it can only be used suspended, since the curls of the osmium filament tend to bend on account of it becoming soft when incandescent.

* Engineer (London).

The current consumption of the tantalum lamp is about equal to that of the osmium lamp; it has, however, the advantage over the latter that, on account of its long filament, it can be used with 110 volts; it possesses the further advantage that it can be fixed in all positions. It may be taken, too, that the tantalum lamp will also be manufactured for higher voltages. The profitable existence amounts to 400-600 hours of illumination, with a total life of over 1,000 hours. Careful protection against vibration is at first not very necessary, but later on it is essential. The filament easily breaks, and even if the single ends on contact fuse together again and the lamp goes on burning, yet such a shortening of the filament takes place that it is soon destroyed on account of the increased current. On the other hand, because the specific resistance of tantalum increases with the rise in temperature, the lamp is not so sensitive to changes in voltage as is the carbon lamp. It gives, like the osmium lamp, a continuously steady white light. A further, if only a small, advantage is that the illuminating surface is larger, and distributed more uniformly over the circumference of the lamp than is the case in a lamp with one or two curves. The tantalum lamp proves to be very regular, and different lamps tested have shown only very little difference from one another. The illuminating power of the tantalum lamp, according to the researches of Ambler, varies with the voltage to a much smaller degree than is the case with the carbon filament lamp. In this respect, the curves of Kenelly and Whiting are considerably different from those of Ambler, in so far as the difference between the tantalum and the carbon lamp is nothing like so large as Ambler makes it. According to Ambler, an increase in voltage of 4 per cent causes an increase in light of about 24 per cent in the case of the carbon lamp, but of only 9 per cent in the tantalum lamp; and in order to produce the same change in the light power in both lamps, the tantalum lamp requires twice as great a change in voltage as the carbon lamp. This small variation in the illuminating power of the tantalum lamp with the voltage can be partly explained by the fact that the tantalum filament, with higher temperature, illuminates as the carbon filament, since with higher temperature the exponent of the absolute temperature, with which the illuminating power varies, decreases. The higher voltage undoubtedly corresponds, however, to higher temperature, and we are therefore obliged to accept that equal changes per cent in voltage in both lamps are followed by equal changes in illuminating power. This observation is only true if the resistance of the incandescent filament in both kinds of lamps changes in the same degree as the voltage. As we have seen above, however, this is not true in this case. This difference need not surprise us, since the tantalum filament possesses the positive temperature coefficient of a metal; the carbon filament, on the other hand, the negative coefficient of carbon. Carbon gradually loses this negative character at first; at a voltage slightly under the normal the temperature coefficient becomes zero, and then gradually becomes positive. This explains the difference in the lamps in respect to light variations; equal increase in voltage results in a smaller rise in temperature, on account of the increase in resistance, than in the case of the carbon filament lamp.

This fact also explains why the specific consumption decreases with the rise of voltage in the case of the tantalum lamp to a less extent than in the case of the carbon lamp. According to Ambler, a 5 per cent increase in voltage made a decrease of the specific consumption of only 12 per cent in the former lamp, but with the latter 30 per cent.

The present considerably reduced price (2s. 6d.), and the higher voltage of the tantalum lamp give it an advantage over the osmium lamp. Unfortunately, the tantalum lamp is not suitable for alternating current, and it is extraordinary that with it the recently manufactured lamps seem to last much less time than when they first appeared. The cause of this most unusual occurrence has not yet been made known.*

The newer zirconium lamps are said to burn, according to the data of their manufacturer and Boje, with 1 watt per candle, the average existence being at least 500 hours. Zirconium lamps are to be brought on to the market adapted for voltages up to 110. The price of a 40-volt lamp amounts to 3s., a 75-volt 3s. 6d., and a 120-volt 4s. Provisionally, however, low-voltage lamps are chiefly manufactured, and the results, communicated by Boje in a lecture, only refer to lamps of low voltage.

The iridium lamp of Gülcher is only manufactured for low voltages up to 24 volts. The price of a 12 or 24 voltage lamp amounts to 3s. 6d. The lamps are said to burn with 1 to 1.5 watt per candle, but reports of comparative results and trials on the duration of burning are not available.

The latest arrival in the field of metallic filament lamps is, as we have previously said, the tungsten lamp. We have to distinguish between tungsten lamps, which are manufactured by four processes. The first process is that of Just and Hanaman. The manufacturers concerned have the intention of producing a normal type of 30-40 candle-power for 110 volts, and with about 1 watt per candle. Researches have been undertaken with these lamps in the laboratory of the municipal electricity works of Munich; the illuminating power is given as 38.9 to 45.7 candles, with a specific consumption of very nearly 1.1 watt per candle.

The second process is that of Kuzel. The Kuzel tungsten lamps were tested in the Sirius works of Kremenecky, in Vienna, and gave for lamps of about 19.32 volts an economy of about 1 to 1.25 watt, with a useful existence of 1,000 hours, in which the average decrease in illuminating power did not amount to more than 10-15 per cent of the original. Several Kuzel lamps were examined at the testing house of the Austrian Purchase Board. A 55-volt lamp showed, at 1.1 watt for one candle, 35 candles; and after 917 hours, 28.6 candles at 1.18 watt for one candle; the decrease in illuminating power amounted to only 7.6 per cent in the 917 hours. According to the assertions of the manufacturers, one curve of the filament will sustain about 30 volts, so that lamps with three filament curves can be manufactured for altogether 110 volts. Burning through is said, as with the tantalum lamp, only seldom to render the lamp useless, and also seldom to have any real effect upon the life of the lamp, since in almost all cases in which the filament parts a fusing together again takes place, so that the lamp burns on again of its own accord. The cost of production is comparatively low, and the greatest efforts are being made to bring the lamp on to the market for the next season.

The tungsten lamps, manufactured according to the third process by the Osmiumlicht-Unternehmung in Vienna, the so-called Osmin lamps, were tested in the laboratory of the municipal electricity works of Munich, and gave at 110 volts, and 1.05 watt for 1 candle, 57.23 candles. The same lamps were further tested in the museum for arts and crafts in Vienna; they burned with 1.03 watt per candle, and after 1,776 hours burning still showed 1.09 watt for one candle. The Osmiumlicht-Unternehmung of Vienna intend to produce lamps of 40, 50, and 60 candle-power for 105 and 110 volts; at 200 volts the lamps will have 80 candle-power. For these types of lamps filaments are required having a diameter of 0.03 mm. A fine human hair has a diameter of about 0.06 mm. One can therefore take it for granted that it will not be possible to manufacture lamps of less than 36 to 40 candle-power for the usual voltage of about 110 volts. This, however, is not such a great disadvantage from one point of view, since this 40-candle lamp, on account of its economy of 1 watt for 1 candle, is equivalent in consumption of energy to a 10-candle carbon filament lamp.

Concerning the fourth tungsten lamp, which is to be brought out by the Deutsche Gasglühlicht Gesellschaft as the Osram lamp, the company itself gives the life, on the average, as over 1,000 hours, during which time no diminution in illuminating power is said to take place. According to a test record of the technical-physical Reichsanstalt, sixteen Osram lamps, of 25 to 32 candle-power, were tested for life and constancy of light by means of alternating current, and the results, on the 21st of May in the current year, at which time the sixteen lamps had been burning 500 hours, showed that, in the case of the 32 candle-power lamps, there was an increase in illumination of about 2 per cent, while the 25-candle-power lamps, compared with their original brightness, had not quite lost 1 per cent. The sixteen lamps burnt out as follows: One each after 156, 512, and 872 hours, two after 700 hours; and it is to be noted that the burnt-through filaments fused together again. After 958 hours' burning, the filament of a lamp burned through and welded together again, so that this lamp, at the close of the experiment on June 28th of this year, was still burning, and therefore reached 1,000 hours. The Osram lamps can be burnt with alternating and direct current, which is important, as it had been shown that the tantalum lamp and Nernst lamp were soon destroyed by the alternating current. The specific consumption of energy amounted, after 500 hours in the case of the 25-candle-power lamps, to 1.12 watt for one candle, and for the 32-candle-power lamp to 1.08 watt for one candle. After 1,000 hours these relations had only changed quite insignificantly. The Auer Gesellschaft intends also to manufacture Osram lamps for 220 volts at 40 and 50 candle-power, with a specific consumption of 1.2 watt for one candle, and from 50 to 200 candles with one watt per candle. According to the assertions of this firm, the life, with full constancy of illumination, amounts generally to over 1,000 hours.

The current consumption of the three ampere Hewitt lamp amounts to 0.33 to 0.15 watt for one candle, which about corresponds to the best results yet attained with the flame arc lamps. With reference to the permanence of the lighting power, and the steadiness of the burning, the mercury vapor lamp has not yet been beaten, particularly as somewhat considerable changes in voltage are without influence. The chief merit of the mercury lamp, however, consists in the fact that no attention and no regulating is necessary, and that the illuminating power, as far as the experiments have yet reached, remains unaltered. The life of the Hewitt lamp, when carefully handled, leaves little to be desired. Lamps which were still in good condition had attained a life of 7,000 hours and more. The price of a mercury vapor lamp of 75 centimeters length, with 500 to 600 normal candle-power, amounts in America, with the inclusion of all accessories, to $30 (£6). The quartz lamp of Heræus, which consists of very expensive quartz glass, transparent for ultra-violet light, costs £15, including the connections. The Uviol lamp of Schott, about 25 centimeters long, with holder, is quoted at £6 5s. We have already stated that the bluish-green color of the mercury vapor lamp, which is very unpleasant, is the chief obstacle in the way of its general introduction.

* According to the latest reports of the manufacturers—Siemens & Halske—the tantalum lamps have recently been much improved, and are now also adapted for use with the alternating current. The average life of the 25 candle-power lamp amounts to 300 to 400 hours, and the 50 candle-power lamp 500 to 600 hours. The lamps are already being used with alternating current. See the Technische Rundschau of the Berliner Tageblatt, No. 46, of November 14, 1906, p. 629.

After these considerations, the question is forced upon us: Which light will finally remain victor, and supplant the usual systems of illumination? Electricity, illuminating gas, petroleum, alcohol, and acetylene have entered into keen competition. Even if enormous strides have been made with the new metallic filament lamps, the efficient results of which, for the development of electro-technics, as a whole, give rise to great hopes, nevertheless it is probable that none of the existing systems of illumination will soon entirely supplant the others. The field is too large, and even if still more new sources of light should be discovered, there is room for all to exist side by side. The light of the old carbon filament lamp is certainly dearer than in all other lamps. Hence it is possible that in future consumers will not employ the carbon filament lamp with its cheap cost of production so widely, on account of its high working expenses.

There is talk of a tungsten lamp having four times the illuminating power of the carbon filament lamp, namely, a specific consumption of energy of about 0.8 watt per candle; some even anticipate 0.5 watt per candle, and the end of the incandescent gas light. It is still, however, a question whether we shall soon really possess an electric lamp so economical as only to need 0.5 watt per candle. At present it is only the optimists who think so, since the new tungsten lamps are not yet out of the laboratory stage of manufacture. The makers are not particularly willing to publish important results prematurely. We have already seen that a large number of inventors are working on the production of the tungsten lamp; it must, however, be noted that in all countries where an examination of patents in respect to novelty takes place, particularly in Germany and Austria, none of the above-mentioned patent applications except the first one by Just have up to the present been accepted. It is yet to be seen which of the various processes can secure effective protection by patent, and it is not yet known which of them in practice will produce efficient lamps.

Whether the new tungsten lamps will fulfill the far-reaching expectations placed in them, cannot, of course, be proved until they have received a thorough trial under practical conditions. Electric lighting with glow lamps has always been a luxury. With a consumption of 0.5 watt per candle, electric light will be just about as cheap as the incandescent gas light, provided the price of electric energy remains what it is at present, namely, 5 to 6 pence per kilowatt-hour.

The difficulty of producing high-voltage filaments from metals with high fusing points, the necessity of using the lamps in prescribed positions, the delicacy of the filament substances, etc.—all these have almost completely been overcome, or, at least, set aside.

PROGRESS IN AIRSHIPS. FORMS OF GAS BAGS.*

By CARL E. MYERS.

PROGRESS in airships seems directed principally to improvement or increase of motive power and variations in the application of the propelling features. Not much consideration seems to be given to the proper form of gas bag or hull, its adaptation to the environment, facility of evolution, or speed, or its maintenance of equilibrium, or long-continued flight.

The crude idea seems to be that any gas body may be pushed speedily through the air if the propelling activity is sufficient.

The correct idea should be to improve the form of gas bag so as to obtain great buoyancy and efficiency with little resistance to progress. The true principle is to increase the propelling effect and decrease the opposition to passage. This seems obvious, just as does the fact that a sharp-pointed nail or needle may be driven through material substance with less force and less resistance than when blunted.

Yet a recent airship, the largest in the world, the "Zeppelin," portrayed on the cover of the SCIENTIFIC AMERICAN of December 22, 1906, resembles a floating log, with rounded ends, of 38 feet diameter, 410 feet long, 367,000 cubic feet capacity, equipped with 70 horse-power, driving four propellers. It presumes a speed of 33½ miles per hour.

Comparison of this aerial log with the fine lines and clipper shape of a modern steamship shows an obvious discrepancy.

The Parseval airship, illustrated in the SCIENTIFIC AMERICAN of November 10, also has a gas bag of this sausage type, about 157 feet long and 26 feet diameter. "The Ville de Paris," illustrated in the SCIENTIFIC AMERICAN of November 17, is shaped forward like an elongated egg, and aft is sausage shaped, with twin links of smaller size attached along its four sides. As a seaship it would be a monstrosity, impossible to propel at half the speed of a plain sausage. I cite the late samples as the possible limit of absurd airship construction of to-day, yet no protest against them has appeared.

Practical tests show that the resistance of air to the passage of a gas body is chiefly of three sorts, which may be termed head pressure, rear suction, and surface friction. A sphere obviously has the least surface for friction. If a sphere is moved through air, there accumulates directly in front a cushion of compressed air, most resistant here. This air relieves its pressure by alternately dodging on either side of the sphere, which reciprocates this action by itself lurching or pitching in a zigzag course. This can readily be observed by towing a small gas balloon on a string. Meanwhile a partial vacuum exists at the rear, where returning air flows inward, at the expense of the propelling force. Each of these movements causes an eddy or vortex, the violence of which represents wasted impelling force. The erratic course of the sphere is wasted travel, but is the easiest means of relief. Hence even a flag wriggles to get past the wind which waves it.

Now, if any cylinder has its ends capped with hemispheres, the same phenomenon occurs, modified by the long sides of the sausage shape. The front air pressure and the rear suction oscillate the body less, while the air pressure flows along the sides in waves of alternately greater and less pressure rearward. The body desires to wriggle like the flag. This rearward-flowing pressure, acting as skin friction, restrains the forward movement of the body in proportion to the surface exposed, which is greater in the sausage than in the sphere, bulk for bulk.

In a properly-shaped gas bag the ordinary skin friction is a greater cause of retarded speed than the so-called "head resistance," which has no actual existence. Hence we should for an airship seek such forms of body as have greatest capacity with least surface resistance, and such entering and departing lines of pressure as leave the air least disturbed, or else convert the disturbed waves into useful work.

In the effort to attain such shapes I have performed numberless experiments, and some dangerous or daring air flights, extending over a quarter century of active professional operations with hydrogen gas vessels, and I have tested in air, water, snow, and earth various forms of projectile bodies, known and unknown. I propose to review hereafter some of these most useful as object lessons in aeronautics.

In the absence of experience in constructing gas bags, those buoyant bodies have been neglected, while the inventor struggled with the mechanism of power, propulsion, and guidance. The commonplace sausage type of gas bag supplied an apparently easy solution of the buoyant problem, and the fitting of some kind of net for harnessing the bag to the suspended car was easier. This has been especially the case in America, and most of the airships have been of that type.

One of the earliest practical airships carrying a man was that of C. F. Ritchel, in 1878. It was a gas bag of about 13 feet diameter by 26 feet long, forming a cylinder having nearly flat ends. Broad webbing bands passed over this cylinder suspended the car below. A small four-bladed fan extended in front of the car and drew it in any direction which its changeable face determined. It was an exceedingly effective mechanism, operated by hand cranks turned by its rider, M. W. Quinlan. The nearly flat ends of the vessel prevented speedy movement. This log form is the worst known.

Coincident with this I conceived a gas kite which avoided this obstacle, and had much greater power. This was a kite surface surmounted on its upper side with the half of a split balloon. It looked like an upturned boat having sharp prow and stern. It was drawn forward and upward by a large screw-sail revolved by hand and foot power, combined with "chainless gear." It mounted facing the wind, drawn up an inclined aerial plane, raising about 50 pounds in excess of its gas buoyancy. At a mile elevation "I was monarch of all I surveyed," and could easily fall in any direction by gravity, guiding by simply leaning to right or left, or forward to descend, as its center of gravity was easily displaced. This machine was superior in accomplishment to anything I have ever seen. It did not satisfy my needs as an exhibitor, because it could not be operated in all weather, as my balloons could, and it was difficult to land this gas parachute in a wind.

I next devised an elongated balloon by omitting a considerable number of segments from a sphere. With this balloon, sharp at top and bottom, I made a perpendicular ascension from Akron, Ohio, September, 1879, and a fall of two miles in two minutes to a safe landing exactly on the spot I had selected from above. The balloon ascended with its neck closed and lashed to the concentrating ring upon which I sat, without a basket, my feet hanging below. Thus I formed the steering rudder going up, and the guiding prow in descending, and the vessel followed my extended legs in any direction, as does the body of any bird steered as always by its beak and extended neck.

I had carried a reliable aneroid barometer, an anemometer, and watch. I knew how much excess buoyancy I had, and my ballast in small bags was weighed. Consequently, I knew the effective effort of my buoyant speed upward, and the equivalent of foot-pounds effort and speed in descending. Upon nearing earth I cast loose the neck of the balloon, which arose by air pressure, forming a resisting surface, and I struck the earth without harm, in a corn field. The experiment was successful, and not expensive. It was the prelude to the construction of a line of variable types of airships which have been remarkably successful with hand and foot propulsion. One such airship made twelve successive flights during five weeks, and returned to the place of departure each time. Another, provided with its own motor, one-fourth horse-power, made a test speed of 12 miles per hour, and ran nearly 700 miles during five weeks' operation.

Returning to the consideration of the sausage-shape gas bag, I have observed in every case where it was forced hard the front end or its part adjacent "caved in" or became hollow at a certain speed, which it could not then exceed. Pitching from loss of gas next resulted.

Another defect of this form of gas bag is the tendency to sink in the middle, of which the "Greth" airship, of San Francisco, and the earliest airship of M. Santos Dumont are examples. This breaking tendency is partly obviated by use of the extended pole keel, or the triangular section frame made conspicuous in Santos Dumont's airships, extensively copied in this country, and provocative of "pitching" in connection with loss of gas. This was remedied to some extent in the Santos Dumont airships by use of the internal air bag. The lurching of gas from one end to the other becomes a dangerous feature in connection with fixed attachment of the suspension lines to a reinforce built in the gas bag to replace netting, which better readjusts the variable strains.

While the use of attached suspension lines instead of netting lessens skin friction during flight, it is an element of weakness in securing a gas bag to its anchorage, when exposed to wind. On the other hand, I have had an inflated airship secured within its own netting exposed for days without loss of gas in a windy "norther" blowing 20 to 30 miles per hour, anchored with sand bags, its sharp point toward the wind.

For safety, economy, carrying capacity, speed, and easy management in air and on earth, the gas bag should have sharp points, and greatest bulk amidships, or where the greatest weight is carried. Either its points or its entire envelope should be continuously distended under some pressure. Its first requisite is a positively impervious gas envelope. How I have obtained this I will explain later at some length.

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

ROMAN FOUNDATIONS—THE WALLS AT RICHBOROUGH, KENT, ENGLAND.

AT Richborough the foundations were thus arranged: First, two rows of boulder stones lie on the natural soil, which is a solid pitsand; then a thin stratum of chalk nodules; next a single row of boulders, and over them another thin layer of small chalk, all these being without cement; then boulders again, mixed with mortar. And so the masonry proceeds internally, with a confused mixture of large boulders, ochre stones, sandstone, and blocks of chalk, the whole cemented with a mortar formed of lime, grit, large and small pebbles, sea shells, and fragments of baked bricks. The outside of the great northeast wall is very beautiful to the eye, as well as magnificent. It is composed, as far as now remains, in general, of seven great and fairly distinct rows of stone, each of them very nearly 4 feet thick, and each of them consisting in general of seven courses of separate stones. The measure of the great combined courses sometimes varies a little, some being 4 feet 3 inches, while others are only 3 feet 3 inches in breadth, or rather in depth, which may, therefore, perhaps, indicate an intention of forming them about 4 Roman feet in breadth or depth upon an average. These great courses of stone are separated from each other by six smaller courses of bricks, composed each merely of a double row of bricks that are about 1½ inches or 1¾ inches in thickness, but are of very different breadths, from 8 inches to 1 foot; and of very different lengths, some being 14 inches, some 16 inches long, and some 17½ inches, a variation of dimensions to be met with in some other Roman structures. For in the old wall of Verulam was a brick, now worked up in the wall of the abbey at St. Albans, which is very nearly 2 feet in length, and there is one at Dover near 3 feet in length. The composition of these bricks is also as various as their dimensions. Some of them are entirely red throughout their whole substance (like our modern bricks), only of a deeper color; some are red on the outside, but of deep blue within, the internal substance being formed of a different earth from the outside (perhaps for the sake of sparing the better and scarcer material). And here, again, we find a great similarity to other Roman works, for in the walls of Chesterford, Verulam, and Silchester are exactly the same varied appearances. Some of the bricks also, here at Richborough, are of a yellow color, having plainly been composed only of mud and clay taken from the neighboring shore. And some of these latter might possibly have been merely dried by the sun; but how the red ones should become of that color without the aid of fire, or how any (except the yellow ones) should have been dried in the sun, as has been hastily conjectured by some antiquaries, is incomprehensible. Let them have been formed how they will, the whole produces still a very beautiful effect to the eye. The structure is everywhere uniformly of this sort of style, except in some very few parts, where reparations have plainly been made in Saxon times, and with squared stones of a much smaller size and with herring-bone work.—The Architect and Contract Reporter.

PROTECTING PIPES FROM FREEZING.

THE means generally employed to prevent pipes from freezing consist in the use of coatings which protect against cold, and non-conductors of heat, such as straw, cork, and oakum. There are, however, more effective agents, also practicable for use in thawing frozen pipes. The pipes are first covered with a thin layer of straw, sawdust or tanbark. Pieces of unslaked lime as large as the fist are then packed around them, and enveloped in another layer of some non-conducting material, straw, oakum, or cork, and the whole is held firmly together by means of a wrapping of coarse linen. The first layer is for the purpose of protecting the pipes from the action of the fresh lime, which would cause the metal to rust. The lime draws moisture from the air and the materials surrounding it, and is made warm by means of the chemical reaction. The outer covering allows only a small amount of atmospheric air to pass through, so that the lime

remains unslaked to keep up the temperature during an entire winter.

This method, with slight variations, can be applied to the thawing out of frozen pipes. For this purpose somewhat more lime is to be packed around the pipes, and water poured over it. The heat generated will melt the ice in the pipes. The ground in winter can also be thawed out in this way, when it is desired to lift paving stones without breaking.—La Technologie Sanitaire.

SIGNIFICANCE OF THE SPIRAL NEBULÆ. A CRITICISM OF THE THEORY THAT THEY ARE THE BEGINNINGS OF STARS.

By PROF. T. J. J. SEE.

For a number of years the writer has given consideration to the probable nature of the spiral nebulæ, and their importance has been considerably increased by photographs obtained by Roberts and Keeler, and more recently at the Yerkes Observatory. Certain speculations have been indulged in which implied that the spiral nebulæ are true nebulæ condensing into systems of stars. Though this premature and unauthorized line of thought has been extensively exploited, it has always seemed to the writer quite unsound. I have consistently held that so far we do not know the true character of the spiral nebulæ. Whether the spiral nebulæ are other Milky Ways, as suggested by Poincaré, time alone can tell; and it may be several centuries before this question can be satisfactorily settled. Meanwhile the exploitation of the spiral form as typical of nebular development is certainly misleading, for, as Poincaré points out, there is no proof that these spirals are true gaseous nebulæ.

Moreover, the writer has shown that we have no proof as yet that the nebulæ really form the stars. The large part played by repulsive forces in nature requires us to be very cautious in concluding that masses of such great extent and irregularity of figure are really condensing. The whole outline suggests repulsion from centers rather than condensation; and such a view is also in harmony with recent investigations of radio-active and other repulsive forces, in the study of which only a beginning has been made.

If we do not know that the nebulæ form the stars, we certainly are not justified in assuming that spiral nebulæ represent a type of stellar evolution, and all such speculations are vague and worthless.

The recent suggestions that the spiral nebulæ, on account of the double ansæ which occasionally project from them, give evidence of tidal disruptions, produced by the passage of some neighboring body, it is needless to say are not only gratuitous, but unjustifiable and in the highest degree improbable. To be of real value a speculation must rest on a *vera causa*, and not assume improbable conditions. The speculations on spiral nebulæ have been decidedly overdone, and it is time to call a halt. There is not the slightest probability that our solar system was ever a part of a spiral nebula, and such a suggestion is simply misleading and mischievous. The great circularity of the planetary orbits shows the absurdity of such an hypothesis, and this leading characteristic of our system as bearing on its mode of origin was carefully considered by Laplace more than a century ago.

At present we must frankly admit that the nature of the spiral nebulæ is quite unknown. And while we cannot be sure that nebulæ develop into stars, we may justly hold that the stars are the outgrowth of gravitational condensation of matter which was once dark.

THE GREAT NEBULA IN ANDROMEDA, CHARACTERIZED BY ITS COMET-LIKE APPEARANCE AND BY ITS PRONOUNCED NUCLEUS

of all can we expect any light from the much exploited spiral nebulæ, which as M. Poincaré justly remarks, may be other galaxies. It is time, therefore, to drop such spirals from our textbooks, or candidly to admit that we are quite in the dark as to their true significance.—Popular Astronomy.

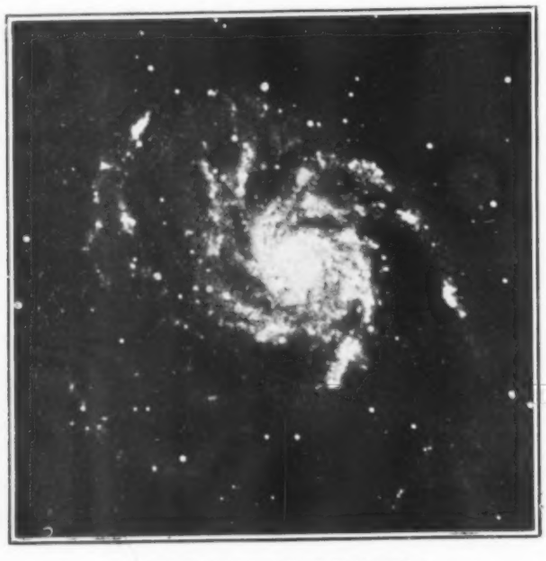
THE TACTICAL QUALITIES OF THE "DREADNOUGHT" TYPE OF BATTLESHIP.

By Lieut.-Commander W. S. SIMS, United States Navy.

In the first place I beg to express the opinion that if Capt. Mahan had been in possession of certain important information that has since become available, his conclusions would have been considerably modified; and while I would not presume to oppose his views as to the conclusions to be drawn from the facts—as he has assumed them, and as he understands them—still I feel I am justified in restating these facts as I understand them, in the light of the new evidence above referred to, and basing thereon my conclusions. Capt. Mahan's principal conclusions may be summarized briefly as follows: (1) That in designing battleships intermediate guns—6-inch, etc.; in other words, that the all-big-gun ship is a mistake. (3) That considering the necessary limits of expenditure and the requirements of a navy with wide naval responsibility, we should not materially increase the size of the ships now being designed.

These conclusions are admittedly derived from, or supported by, an analysis of the available information concerning the battle of the Sea of Japan. In the same number of the Naval Institute Journal in which Capt. Mahan's article appears there is published a very important paper giving a history of this battle that is founded on very precise notes. The author of this paper, Lieut. R. D. White, U.S.N., a distinguished gunnery officer and naval constructor, having no station in battle, was selected to observe and record the events of the battle. As my principal reasons for dissenting from Capt. Mahan's conclusions are based upon the assumption that the facts in this account are correct, I will take the steps necessary to mention an interesting incident that tends to show the correctness of Mr. White's chart (Fig. 1), and that also gives a practical illustration of an important feature of tactics in relation to gun-fire—a feature that gunnery officers had already recognized in discussing the theory to which it will be necessary to refer later.

Analyses of this battle-chart were made and curves drawn to illustrate at all stages of the action "the rate of change of range." "After marking the times



THE SPIRAL NEBULA IN URSA MAJOR.

THE SPIRAL NEBULA IN CANES VENATICI.

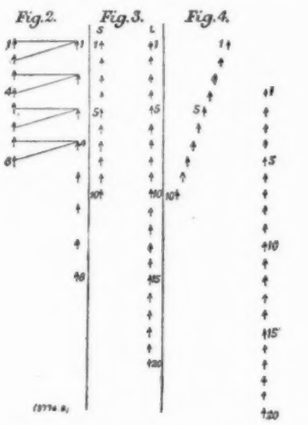
THE CREATION OF A STAR.

The closeness of most revolving double stars seems to indicate that separation takes place in the stellar rather than the nebular stage, and this leads us to doubt whether the forms of the nebulæ can be expected to disclose the processes of stellar evolution. Least

of these curves, and plotting the positions of the two fleets at those times, we found, on comparing them, that the Russian ships were driven out of the line of battle or sunk only when the rate of change of range was small, and that when this rate was large there was little or no evidence of damage being done by gun-fire." This coincidence of time, "rate of change of range," and destruction of ships is strong evidence that Lieut. White's chart is correct, otherwise there would be no coincidence. Further corroborative evidence is given later.

As this question of the rate of change of range undoubtedly had a direct bearing upon Admiral Togo's tactics, it should be explained that experiments have shown that it is exceedingly difficult to hit an enemy at long range when the range is changing rapidly. This is, of course, not true at short range, but at long ranges the half-danger spaces—those at which the gun-sights must be set in order to hit—are so small, say, 50 yards. The bearing of these facts on naval tactics is very important, since it means that, generally speaking, you cannot make many hits at long range while you are maneuvering. Conversely, you will not receive many hits during such a time, because, when at short ranges, the most dangerous position in which a ship can place itself is end on to the enemy. It is usually assumed that this is equally true at all ranges; but this is not the case provided the rate of change in fire is rapid. A reference to the chart will show that upon three occasions during the action Admiral Togo did not hesitate thus to expose his ships, and that at none of these times was any material damage done.

Capt. Mahan has assumed that shortly after the Russian and Japanese fleets sighted each other the Japanese changed course from southwest to east, while the Russian and Japanese fleets sighted each other the Japanese speed was slower than that of the Russian. Under these conditions—that is, with the course assumed—the rate of change of range would have been very rapid, and therefore very little hitting could have been done. As a matter of fact, the Russians were steering about north-northeast, and the Japanese, after turning from southwest to east, took a course nearly parallel to them on their port bow. Thus the rate of change of range was rendered small, and the Japanese fire was concentrated on the head of the Russian column, and was so effective that the "Suvaroff" was driven out of the line, and the "Osliabia" sunk by the time that the Russians had advanced five miles. The above shows that the nature of the action was rather different from that which Capt. Mahan's information led him to suppose. It is therefore unnecessary to follow out the details of the reasoning by which he assumes that Admiral Togo was influenced in taking a



position (across the head of the enemy's column) which he did not take; for it is important to point out that the Japanese admiral's plan of action was what we would have supposed it to be, in the light of our present knowledge of the conditions necessary to the mean effective hitting at long ranges. In the first place, it may be confidently assumed that Togo was in possession of the following important facts: (1) That his fleet's speed was considerably greater than that of the enemy, the bottoms of his ships being clean, and theirs foul, and there being slower ships in the Russian fleet than in his. (2) That his marksmanship was superior to that of the Russians. (3) That the Russian gunnery training had for years been carried out with the object of bringing the enemy to close quarters, and that, even assuming that they had profited by their experience in the actions off Port Arthur, the Baltic fleet could not have had adequate training in long-range fire. (4) That in order to render effective the tactics indicated above the Russian ships were heavily armed, and their crews trained for rapidity of fire. (5) That effective hitting at long range can be done only when the rate of change of range is comparatively small.

The above being true, it is clear that Admiral Togo must have gone into action with two principal objects clearly defined in his mind—namely, (1) fighting at the maximum range at which actual experience of battle practice had shown him that he could do effective hitting—namely, at about 6,000 yards—and at which he knew that the Russian fire would not be dangerous; (2) so to maneuver as to maintain the least practical rate of change of range as frequently as possible upon the head of the enemy's column. If he had not been able to accomplish these two objects, he might still have won the battle, because the Russians were so very inferior in many other respects; but he certainly would have suffered more. For example, if the Russians had been able by superior speed to run in to 1,800 yards—the battle-range of their choice—they would have made a large percentage of hits, and these hits would have been very effective, especially from their modern ships of French design—the "Suvaroff," "Alexander III," "Borodino," and "Orel." A glance at Lieut. White's chart will show, however, that the Japanese admiral had no difficulty, barring thick weather, in repeatedly choosing his own position, distance, and bearings with reference to the head of the enemy's fleet, and the battle therefore resolved itself into a competition between the fire-control officers of the two fleets.

Let us now consider the manifest object of the Russian admiral's strategy and tactics with a view of determining why he was unable to succeed. In the first place, the Russian battleships were so overloaded with stores and coal that the upper edges of their heavy armor plates were well below the water-line, and therefore, in so far as the hull protection was concerned, they were armored cruisers, and not battleships. Also, that the compartments, cabins, passages, etc., were so filled with coal and stores that the men's water-closets and urinals had been blocked since leaving Leghorn, and the decks were in consequence in an indescribable condition. We may therefore safely assume that the Russian admiral approached the Tsushima Straits with two objects foremost in his mind. The first, and most important, was to elude the Japanese and take shelter in Vladivostock until he could land his stores, dock, and refit his ships. Second, if forced to fight, to do so at the shortest possible range, where most of his shots would count. He was defeated in both of these objects solely by the superior speed of the Japanese, assuming, of course, that he could not pass through the Straits without being detected. Once he was sighted by the Japanese (which was inevitable), their superior speed—which, as shown later, was six to seven knots greater than that of the Russians—rendered impossible his escape without fighting, and, as previously shown, this superiority of speed enabled the Japanese repeatedly to concentrate upon his leading ships, and thus destroy or disable them one at a time, or force them to accept defeat in the worst form—namely, by abandoning their attempt to reach Vladivostock, thus surrendering the command of the sea without inflicting any damage upon the enemy.

It is, of course, understood that, assuming all other qualities to be equal, a relatively small superiority of speed cannot alone determine the victory by gun-fire under the usual "game-board" conditions—that is, where sea room is unlimited, where it is always daylight, and where thick weather does not act as an occasional screen; where the slow fleet is not embarrassed by having to get anywhere in particular; where there is no convoy or fleet to lose in case of retreat, etc. In this case the slow fleet can prevent the fast one from taking up a position of continuous advantage by simply keeping ahead of the enemy's column abeam, thus training on the arc of a circle of a sufficiently small radius to counteract the superiority of speed of the fast fleet. The sole tactical ability of the slow fleet is a negative one as regards gun-fire; it can never attain the advantage of position, assuming equal skill on both sides. Its tactical ability exists only in the open sea, and even then the faster fleet has the great advantage of being able to first refuse or accept battle, to choose its own range, to control the rate of change of range, and to control compass bearing, thus taking advantage of the weather conditions that control its own gun-fire.

It follows from the above that the slow fleet must

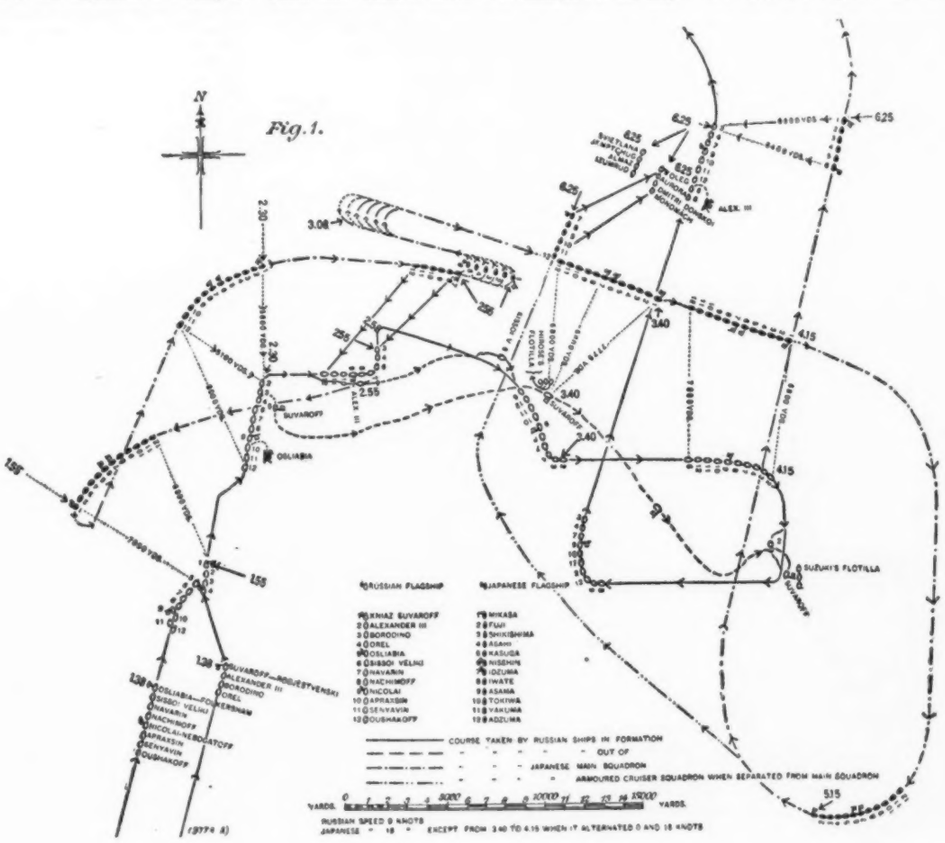


Fig.1.
N
RUSSIAN FLAGSHIP
JAPANESE FLAGSHIP
COURSE TAKEN BY RUSSIAN SHIPS IN FORMATION
OUT OF
JAPANESE MAIN SQUADRON
ARMOURED CRUISER SQUADRON WHEN SEPARATED FROM MAIN SQUADRON
RUSSIAN SPEED 9 KNOTS
JAPANESE " 18 "
EXCEPT FROM 3.40 TO 4.15 WHEN IT ALTERNATED 0 AND 18 KNOTS

always fight at a disadvantage, even in the open sea, and that when restricted in its movements by the neighborhood of land or shoal water, by the necessity of protecting its engine auxiliaries, by the necessity of reaching a definite point, or by the necessity of leaving a port in the face of a blockading enemy, it must inevitably be defeated even by a faster fleet of equal power, and can be defeated by a faster fleet of less power. From the above it seems clear that in the light of our present knowledge of the fundamental principles of long-range gun power, a superiority of speed that will enable a fleet frequently to concentrate its fire on an enemy who is not entirely unrestricted in its movements, as above explained, is more important than the additional gain corresponding to the weight in boilers and engines required to give the superiority in speed.

Capt. Mahan estimated that the Russian fleet maintained on May 27 a fleet speed of at least 12 knots, while the Japanese seemed not to have used more than 15 knots. Lieut. White's information states that the Russian fleet speed was 9 knots, and the Russians estimated the Japanese speed at 16 knots. As Lieut. White's chart is a chart plotted to scale from the precise data taken by his informant, and not simply a diagram to illustrate his text, it follows that if we measure the distance steamed by the two fleets from 1:55 P. M. to 6:25 P. M. (four to five hours), and divide this distance by the elapsed time, the results will be complete speeds, though the calculation will be rough, as the scale of the chart is small. This calculation shows that during the four to five hours the Russians steamed 40 miles, while the Japanese steamed 68. This gives the average speed of the former as a little less than 9 knots, and that of the latter as a little more than 15 knots. It should be noted, however, that the Japanese speed alternated 0 to 16 knots between 3:40 and 4:15; therefore their average speed was probably considerably more than 15 knots. The Japanese superiority in speed was therefore more than six miles an hour, an advantage so enormous that no conceivable strategical or tactical skill, and no possible augmentation of gun-fire (without increasing the displacement) on the part of the Russians could have prevented their defeat, even supposing a rudimentary knowledge of strategy and tactics on the part of the Japanese admiral, and assuming, of course, that the Russian fleet was constrained to force its way sooner or later through the Straits. If the speeds of the Japanese and Russian fleets had been reversed, Admiral Togo could not possibly have prevented the Russians, first, escaping to Vladivostock, or, second, bringing the Japanese to battle at short range if they had so desired. Furthermore, Admiral Togo's comparatively easy strategy would have been so modified by a reversal of the speed conditions that he would have been obliged to await the Russians at Vladivostock, out of range of the outer ports, in a region of frequent and dense fogs, and do what damage he could as they passed in. It may also be pointed out that shortly after 4:15 P. M. (see the chart) the Japanese lost sight of the Russians, due to thick weather, and steamed seven or eight miles to the southward in search of them, and when they turned to the northward in pursuit they were about ten miles astern. Therefore if the Russians had had even a quarter of a knot superiority in speed, they would have arrived ... Vladivostock a couple of hours ahead of their pursuers.

It is true that the speed of a ship may be reduced by damage to the motive power of one of its units; but this has very rarely happened, because engines, boilers, etc., are below the water-line, and well protected by the best armor. Capt. Mahan lays great stress upon the alleged difficulty of the loss of funnels or smoke-pipes, showing that the resulting decrease of speed would be so great that the loss of a modern funnel would be like the loss of a former-day mast. This appears to me to be a great exaggeration. As I understand this matter, the principal reason for building a tall funnel is for increasing the natural draft, and thus render steaming more economical in time of peace. Tall funnels have always been a mistake from a military point of view, because when the vessel having them goes into battle, and forced draft is put on to develop her maximum speed, the tall chimney adds very little to the draft by reason of its height. We may regard their being shot away, or riddled with holes, with comparative equanimity—provided they do not fall on deck and disable guns; since in every case the draft will not be materially decreased, as the high funnel corresponds to a pressure of about ½ inch of water, whereas blowers will create a pressure corresponding to about 2 inches of water.

It may be well to notice, moreover, that the requirements of fire control necessitate much shorter funnels, because gun-fire can be controlled efficiently only from elevated platforms on the masts (about 100 feet from the water); and as funnels cannot be made high enough to carry the smoke over these platforms, they must be so low that the smoke will not reach them.

Concerning the advisability of building "all-big-gun" ships—that is, discarding all smaller guns, except torpedo defense guns—and designing the ships to carry the maximum number of heavy turret guns (these alone to be used in battle), I think it can be clearly shown that Capt. Mahan is in error in concluding that it would add more to our naval strength to spend the same amount of money that the big ships would cost for smaller and slower ships carrying the usual intermediate guns—6-inch, etc.—and that it is only a question of speed; this error is probably due to the fact that much important information concerning the new methods of gun-fire was not considered by the author in preparing his article.

In order that this question of gun-fire may be clearly understood, it will be necessary to mention the fundamental principles of fire control. In order to hit at long ranges you must have the sight-bar range within small limits—that is, one-half the danger space. No existing range finder will measure such long distances within these limits. With the ammunition carried by ships in service (that is, ammunition that is not new) this sight-bar range usually differs for each index of power, even for guns of the same caliber, and the sight-bar range for one caliber is rarely the same as that for any other caliber. Therefore there must be a separate fire-control for each caliber on board, which greatly increases complication and difficulty of control when there is more than one caliber. Since the range-finder can never be relied upon, it follows from the above that the sole means of bringing the sights on to an enemy, and keeping them there, is by observing the splash of projectiles from aloft by the vertical method. If a ship has guns all about one caliber, fire control is comparatively easy, because each splash is necessarily made by that caliber, and the fire of the ship is controlled by one fire-control officer (directing one fire-control party). When the distance is over 5,000 yards you cannot follow the projectiles throughout their flight, and identify their splashes, unless the projectiles of the different calibers differ greatly in diameter—as 12 inches and 6 inches—and consequently make splashes that are markedly different in size and appearance.

Therefore we have to decide what the caliber for each class of ships should be, a decision which should present no special difficulty provided it be first determined how and where to defeat the enemy—whether by the destruction of their ships by sinking them, or disabling their guns, or by the destruction and demoralization of their personnel. In this connection the following facts should first be clearly understood—namely, turrets are now for the first time being designed that are practically invulnerable to all except heavy projectiles. Instead of having sighting hoods on the turret roof, where sight pointers and officers are exposed to disablement (as frequently happened in Russian ships), there will be prismatic sights projecting laterally from the gun trunnions, through small holes in the side walls of the turret; and the gun ports will be protected by 8-inch armor-plates, so arranged that no fragments of shells can enter the turrets. On the proposed "all-big-gun" ships the heavy armored belt will be about 8 inches thick above the water-line, extending from end to end; the conning tower, barbettes, etc., will be of heavy armor, there being no intermediate battery (which could not be protected by heavy armor on account of its extent). It follows that in battle all of the gunnery personnel, except the small single-fire control party aloft, will be behind heavy armor, and that therefore neither the ship nor her personnel can be materially injured by small-caliber guns.

Considering, therefore, that our object in designing a battleship is that she may be able to meet those of our possible enemies on at least equal terms, it seems evident that it would be extremely unwise to equip our new ships with a large number of small guns that are incapable of inflicting material damage upon "all-big-gun" one-caliber ships of our enemies, or upon the personnel manning their ships.

It is necessary to describe the method of controlling 6-inch guns in order to show that Capt. Mahan's apparent impression as to their efficiency in battle is probably very largely in error, as shown by an analysis of the results of battle practices and of the rapidity of hitting of these guns in the battle of the Sea of Japan. We have sufficiently complete information concerning these practices, and the indisputable lessons taught by them; and our development was based thereon, and has proved successful. Briefly these lessons are as follow: If the pointer aims through the heated powder gas from another gun, as soon as he can make out the target, he will almost always miss, because the heated gas refracts the line of sight. He must therefore wait until he has clear air to aim through. The loss of time due to this cause is termed the "interference" of one gun with another's fire. In attempting to make the greatest possible number of 12-inch and 6-inch hits on a run after a certain length of time (the measure of the efficiency in fire), it was found that when the 6-inch guns were allowed to fire at will, the interference caused by the frequent puffs of gas from them—about one puff every two seconds—was such as to diminish so seriously the rapidity of hitting of the 12-inch guns, especially those of the after turret, as to render it entirely inadmissible that these guns should fire at will, simply because the ship could do an enemy more damage by discontinuing their independent fire entirely, and using the 12-inch guns alone. It was therefore determined to try to decrease their interference by firing them all at the same time—that is, by salvos. This was found to be unexpectedly successful, as by this method more 6-inch hits per gun per minute were made than when these guns were fired independently. Salvo firing is possible only with guns that are capable of continuous aim—that is, intermediate guns of 6 inches in caliber or less. It is, of course, not possible with 8-inch guns, depending upon the facility with which the pointers can maintain a continuous aim in elevation. When 6-inch guns are fired single, their average rapidity of fire is about seven rounds per minute. When these guns fire salvoes, their rapidity of fire does not average more than four rounds per minute, the best so far attained being five rounds per minute. When firing at short ranges the percentage of hits made by guns of different calibers varies with the caliber, thus the larger the gun the greater the percentage of hits. When firing at long ranges the same law holds, except that the larger calibers have then a much greater advantage, because their angle of fire is much less than that of small guns, and, consequently, their danger space is much greater. For example, at 6,000 yards a 12-inch gun, having an initial velocity of 2,400 feet per second, has an angle of fall of 4.75 deg., while that of a 6-inch gun having the same velocity is 8.50 deg., and the respective danger spaces for a target 30 feet high are respectively 120 and 64 yards.

This illustrates how much more difficult it is to hit with a 6-inch than with a 12-inch gun, which makes it clear, I believe, that Capt. Mahan is greatly in error in saying that if we determine the number of shots fired by each caliber, we may assume "as probable a proportionate number of hits." As a matter of fact, Capt. Mahan has drawn his conclusions from the "volume of fire" of the different calibers, instead of from their volume of hitting, or rapidity of hitting, which is our present standard of efficiency for all kinds of gun-fire. He has also assumed that the Japanese rapidity of 6-inch fire was about twelve times as great as that of the 12-inch fire, but, as a matter of fact, it was probably not much more than twice as great. We have, of course, no actual figures, but as we know that our 12-inch guns can fire two shots a minute (and with improved loading gear we expect to fire three shots per minute), and that 6-inch salvo firing is at the rate of four shots per minute, and, as we also know, since 1901 the Japanese have used the same methods of training, we may safely assume that the relation between their 6-inch and 12-inch rapidity of fire is about the same as ours, though both calibers may be actually less or more rapid. Lieut. White estimates that the Japanese fired 1,275 heavy shell (12-inch), and made 250 hits, or 19.6 per cent, which was good shooting considering the long ranges and the unfavorable weather. As for the 90-odd secondary guns (Capt. Mahan's estimate), if we assume that, on an average, each fired 2½ times as many shots as each 12-inch gun, the total number of shots was 86,175 ($2.5 \times 75 \times 90$). If they had made a "proportionate number of hits," or 19.6 per cent, they would have secured 3,307 hits, or about thirteen times as many as the 12-inch hits, which we know they did not make.

Unfortunately, we cannot obtain the exact figures, though we can make an estimate that will be close enough to show the comparative hitting capacity of these guns. They fired 50 pounds of small projectiles for every pound that hit, whereas they fired only 5 pounds of 12-inch metal for every pound that hit, which accords with the law that we have deduced from our target practices—namely, that the smaller the gun the more projectiles you must waste to make a hit. But as the Japanese battleships and armored cruisers carried these guns, they were, of course, justified in firing them as best they could, without diminishing the rapidity of the 12-inch guns. They did not, however, fire off all their small guns—those less than 6 inches—because to do so would have caused too much "interference" with more important guns, though the hail of small projectiles, that is so popular in newspaper accounts, would have been very effective if they had hit.

If the Japanese vessels had been designed in accordance with the principles of modern gun-fire—had been all-big-gun ships—their fleet would have developed a greater rapidity of hitting with heavy guns (875 hits) than it actually did develop with 12-inch, 8-inch, and 6-inch guns (700 hits), and this for the simple reason that at long ranges the hitting capacity of their heavy guns was 19.6 per cent, while that of the smaller guns was only 2.1 per cent. Moreover, as a matter of fact, a fleet having but one caliber of heavy guns on each vessel would have been able to make still more hits in the given time, because their fire-control officers would not have suffered from the interference caused by the more numerous smaller guns. Thus we see that at modern battle-ranges, an all-big-gun fleet will actually deliver a greater volume of hitting (a greater number of hits)—twice the weight of metal hits, and twice the weight of bursting charges—than a fleet of mixed-battery ships of the same nominal power. As to the comparative moral effect of the explosion of 12-inch and 6-inch shells, it seems to me that, when we compare the difference in the weight of the bursting charges (that of the 12-inch 38 pounds, while the 6-inch is only 4 pounds) and the difference in the strength of the walls of the shell, there can be no doubt that the moral effect of the former is very much greater than that of the latter.

But it may be asked how can we account for the fact that until recently practically all naval officers have favored ships with two or more calibers of main-battery guns. The explanation is afforded by a statement made in the annual report of the Chief of the Bureau of Ordnance about 1902, to the effect that it was not considered advisable to increase the number of heavy guns on battleships, because the greater the caliber of the guns the less their hitting capacity, due to the weight to be handled in aiming, etc. While this may have been true to a certain extent during the time that we paid practically no intelligent attention to shooting, it ceased to be true as soon as the present competitive system of training developed the real hitting capacity of these guns, thus reversing this supposed law, and showing that the true law was, as should have been recognized, in perfect accordance with the ballistic properties of the various calibers.

Referring now to a point previously indicated, but not explained, I beg to invite special attention to the tactical advantage that we shall gain by having battleships of large displacement, an advantage which ap-

pears to me so great as to entirely outweigh all the alleged advantages of numbers mentioned by Capt. Mahan. This may be best illustrated by contrasting the tactical qualities of two fleets, one of large vessels and one of small. Before doing so, however, it may be well to state my understanding of the principal tactical qualities which are desirable in the fleet. These are, first, the compactness of the battle formation; second, the flexibility of the fleet as a unit—that is, its ability to change its formation with the least possible time and space with safety to its units. For example, suppose two fleets of eight vessels composed of ships that are alike in all respects, and suppose their personnels to be equal, with the exception of the commanders-in-chief—whose difference in skill and ability is such that one fleet has been so drilled as to be able to maneuver with precision and safety, while maintaining one-half the distance between its units that the other fleet requires. This is putting the extreme case, but it shows first that the short fleet, being about half the length of the other one, can complete certain important maneuvers in about one-half the time and one-half the space required for similar maneuvers of the long fleet. (2) That when ranging alongside each other, as shown in Fig. 2, defeat of the long fleet is inevitable, since rapidity of hitting of the individual units is assumed to be equal, and each of the four leading ships of the long fleet receives about twice as many hits as she can return, though the eighth ship of the short fleet would suffer a preponderance of the gun-fire from the fifth or sixth vessel of the long fleet, the seventh and eighth being too far astern to do much damage, as would also be the case if the long fleet had several small vessels astern of this. This is because of the principle here illustrated—that the constant effort of the competent flag officers is to reduce the distance between the units of their fleets to the minimum that can be maintained with safety under battle conditions—that is, while steaming at full speed, without the aid of sextants and other appliances that should be used only for preliminary drills.

Doubtless some flag officers by constant competitive exercises in maneuvering may succeed in attaining an interval between ships that is less by 15 per cent or 20 per cent than that attained by others; but manifestly there is hardly any possibility of much greater improvement in this respect, because the minimum practical interval between ships depends upon their lengths and maneuvering qualities. For example, the normal interval is 300 meters from center to center; while larger ships, of, say, 400 feet long, require about 400 yards, and those between 450 feet and 500 feet in length require about 450 yards. If we accept Capt. Mahan's advice and build comparatively small low-speed battleships, while our possible enemies build large, swift, or big-gun ships, it seems clear that we shall sacrifice the enormous advantages of fleet compactness and flexibility, the superior effect of heavy gun-fire, and the ability to concentrate our fire—the loss of these advantages to be fully realized twenty-five years hence, when our enemies have fleets of big ships, while we still have those of our present type.

In order clearly to illustrate the above, I will assume that a fleet of ten 20-knot battleships, of about 20,000 tons displacement, each having a main battery of five 12-inch double-gun turrets, or a broadside fire of eight 12-inch guns disposed as in the "Dreadnought" type—that is, one turret forward, one on each beam, well forward, and two aft on the center line. Assume the cost of these ships to be 10 million dollars each, or 100 millions for the fleet, and assume that the same sum of money will build twenty battleships (though the number would in reality be considerably less) of the smaller type of, say, 13,000 tons and 16 knots speed, each ship armed with two 12-inch double-gun turrets, or a broadside of four 12-inch guns, and as many of the smaller guns recommended by Capt. Mahan as can be mounted upon this displacement. It is further assumed that as all the gun crews of the fleet are behind heavy armor in the 12-inch turrets of new design, neither the crew nor guns can be materially injured by the intermediate guns of the fleet of small vessels; whereas, on the contrary, the majority of the men composing the gun crews of the small vessels (all but about ninety for the two 12-inch turrets and their ammunition supply) are behind the armor of the intermediate guns, necessarily light on account of its great extent; and these guns and their crews must be disabled or destroyed early in the action. It is therefore evidently well within the truth to assume that the gun-fire of each large vessel will be more than twice as effective as that of each small one.

If the length of a large ship is 500 feet, and the small one 400 feet, and the interval between centers is respectively 450 yards and 400 yards, it follows that when in column the long fleet of small vessels is 3.9 miles, while the short fleet of large vessels is 2.1 miles. That is to say, the long fleet has a broadside fire of less than twenty-one big guns for each mile of length, while the short fleet has thirty-eight guns per mile, with concentration of gun-fire that is inherent in the design of the large vessels, and which no conceivable technical skill on the part of the small ones could offset.

The technical advantage of this concentration of gun-fire is shown graphically in Fig. 3, which shows "S" in a position of disadvantage; it is apparent that the first nine vessels of the "L" fleet may be destroyed by the first nine of the "S" fleet, since the latter have more than twice the gun-power of the former, while No. 10 S can sustain the fire of both 10 and 11 L, but not that of 12, 13, and 14 L also. Assuming, however, that the fourteenth vessel of the "L" fleet is the last one whose fire would be effective against 10 S, the rear vessels of the "S" fleet might, by reason of having more than twice the individual gun-fire of their individual opponents, protect themselves by dividing the fire of 10 S between 13 and 14 L, 9 S between 11 and 12 L, 8 S between 9 and 10 L, and 7 S between 7 and 8 L, thus leaving the first six vessels of "L" to be destroyed by twice their gun power from the first six vessels of "S," an advantage that is possible only with big ships; and this advantage is of great importance, because when the "S" fleet is taken at a disadvantage it enables each of its vessels to hold her own against at least two of the enemy.

Observe that even when the "L" fleet is in the advantageous position shown in Fig. 3, no increase in the number of vessels of the "L" fleet can possibly prevent the successive destruction of the leading vessels, since the vessels behind No. 14 are practically out of action. Observe, also, that if for any cause the "L" fleet should be restricted in its maneuvers, the "S" fleet, instead of exposing its rear vessels to concentrated fire, as in Fig. 3, would take advantage of its superior speed, and assume the position shown in Fig. 4, thus concentrating upon the leading vessels of the "L" fleet its entire gun-fire at a greater or less average range. This would be possible if the positions of the fleets were reversed; that is to say, the concentration of the "S" fleet upon the leading vessels of the "L" fleet, Fig. 4, is very much more intense than would be the concentration of "L" upon the leading vessels of "S."

It would therefore appear that from the tactical point of view alone the advantages of large vessels are such that they afford greatly increased offensive power when in a position of advantage, and greatly increased defensive power when in a position of disadvantage. It should also be noted that if through an accident to the motive power of the large vessel the fleet speed of "S" were reduced to that of the long fleet, the "S" fleet would still be the superior tactically, because it is more compact (is shorter, and has less units), and can therefore maneuver with greater ease, and frequently in much less time; an advantage that is in some cases analogous to superior speed.

For example, the time necessary to indicate a signal to the twenty vessels of the "L" fleet, and before it is understood, and for this fleet to complete a change of course in column, so as to make a simultaneous movement, would be at least twice as long as that required for the ten vessels of the "S" fleet. It follows, of course, from the above that as soon as we build any fast vessels of the large displacement above indicated, and put them in the line of battle with 16-knot ships, we strengthen the fleet much more than if we had as many 16-knot ships as could be built for the cost of the big ships. For though we cannot at once utilize the superior speed of the big ships, we have nevertheless increased the compactness of our ships by diminishing the number of units, and therefore, for the reasons given above, have rendered it a superior tactical unit, which means that, with equal skill, it would out-maneuver a fleet of the same cost composed of small vessels throughout.

It should be noted also that if we place two only of these battleships at the head of a column of small vessels, each having one half of the broadside fire of the former, we not only render the fleet more flexible, being shorter by more than 2,000 feet, but we strengthen our fleet at the weakest point by concentrating within a distance of 1,800 feet a broadside fire equivalent to that of four vessels occupying a space of 4,000 feet. The above advantages are evidently so great that the alleged value of homogeneity of units is not worth considering.

Concerning the alleged strategic value of numbers, and assuming that Capt. Mahan's statement that "a nation with wide naval responsibilities must have numbers in proportion," means that we had better spend our available appropriations in building small vessels rather than large ones, in order to facilitate dispersing them all over the world, I beg to say that in my opinion the above analysis shows very conclusively that a fleet of the large vessels is greatly superior in fighting value to a fleet of small ones, no matter into how many equal squadrons of, say, four or more vessels we subdivide them. For example, for $280,000,000 we could build twenty-eight of the "Dreadnought" class, forty "Connecticuts," or four squadrons of seven and ten vessels respectively. The former squadron would be 1.4 miles long, with a broadside fire of forty 12-inch guns per mile, and the latter 2.1 miles long, with a broadside fire of twenty 12-inch and twenty 8-inch, neglecting the smaller guns as not effective against any armor of the "Dreadnought" class. The above assumes that a nation of even the widest naval responsibility would ever deem it possible to disperse their naval units throughout the world, even in time of peace, thus diminishing individual efficiency, unity of purpose and action, and the indispensable ability to maneuver large fleets at battle speed. Rojhdestvensky's fleet had been maneuvered but once as a fleet before the battle of the Sea of Japan.

I had always supposed that the subdivision, in time of peace, of a nation's fighting units into numerous independent squadrons was due more to personal reasons than to a consideration of the principles of naval training and strategy, as illustrated by the rapid concentration which takes place when war is imminent. I understand that where the command of the sea is involved, a nation is not debarred from going to war by the state of distribution of the rival nation's battleships, but by the knowledge that they have a certain number, that they possess certain material fighting qualities, and that they have been continuously trained to a high degree of individual and fleet efficiency by concentration in one or more large fleets.

If it be claimed that it would be better to reduce the speed of the large vessels to 16 knots, and put the weight saved into guns, it may be replied that heavy turret guns cannot be mounted (so as to increase the hitting capacity of the vessel) without very considerably increasing the size of the ship, because the number of heavy turrets that can be placed to advantage is governed largely by the length of the ship, which increases slightly with the displacement. This point is fully discussed in a recent article in a German publication. I do not remember the displacements used by the author to illustrate the principle, but, supposing the ones quoted below to be correct, he shows that if it requires a displacement of 20,000 tons to obtain a broadside fire of, say, eight 12-inch turret guns, you could not advantageously mount any additional turrets on 21,000 or 22,000 tons, but would have to go to 25,000 tons or 26,000 tons to obtain the necessary space. Conversely, if you design a 20,000-ton battleship for 16 knots instead of 20 knots, you cannot utilize the weight saved to increase the gun power by adding 12-inch turrets, as you can by adding a number of intermediate guns. It is now hardly necessary to state that adding superimposed turrets, by which the number of guns can be doubled (for a given weight) does not materially increase the hitting capacity of the ship as a whole, because of the interference caused by having four guns in one two-story turret, while it decreases her defensive power by adding to the vertical height of her vital target.

Capt. Mahan characterizes the sudden inclination of all navies to increase the size of the new battleships from about 15,000 to about 20,000 tons as "willful premature antiquating of good vessels," a "growing and wanton evil." It seems to me that the mere fact of there being a common demand for such vessels is conclusive evidence that there must be a common cause that is believed to justify the demand. This common cause is undoubtedly the common belief that the same amount of money expended for large war vessels will add more to a nation's naval power than the same amount expended on smaller vessels.

It should never be forgotten that the credit for the inception of the epoch-making principles of the new methods belongs exclusively to Rear-Admiral Percy Scott, director of target practice in the British navy, who has, I believe, done more to improve naval marksmanship than all the naval officers who have given their attention to this matter since the first introduction of rifled cannon on men-of-war.

From the point of view of naval efficiency, we should have nothing to fear from even a still further increase in the size of our battleships. For example, reverting to the supposed fleet of ten 20-knot ships, the "S" fleet, above described, there can be no doubt that the same sum—$100,000,000—expended for a less number of still larger battleships would produce a superior fighting fleet. For the same sum we could doubtless build eight ships, each having a broadside fire of ten 12-inch guns instead of eight, with 1 knot more speed. Such a fleet would be 1.7 miles long instead of 2.1 miles, with the concentration of 48 heavy guns per mile to oppose to the 21 per mile of the long "L" fleet (3.9 miles) of small vessels, not to mention the increased superiority of its maneuvering qualities, and the superiority of its protection against gun-fire and torpedoes. One of the great advantages with a large vessel is that the underwater hull may be so designed that the ship cannot be materially damaged by one torpedo.

A brief explanation is now required as to why Prussian and American naval officers are practically a unit in advocating the all-big-gun one-caliber ship, while some other navies, discarding the small guns—6-inch, etc.—still retain in new designs large turret-guns of two calibers, as 12-inch and 8-inch and 11-inch and 9.2-inch, etc., the larger turrets being in the bow and the stern, and the smaller ones on the sides. The reason is, I believe, that they do not yet understand the great difficulty of controlling the fire of guns that approach each other in caliber. From the facts and arguments presented I derive the following main conclusions, formed upon what I believe to be fundamental theoretical principles of gun-fire and tactics: (1) That in consideration of the fact that the ultimate object of the fleet is that in the event of war we may be able to overcome our possible enemies on the sea, we should so design our battleships that they will at least equal those of our possible enemies in all of their fighting qualities—speed, gun power, height of gun positions, protection, etc. (2) That, subject to the above requirements, it is always desirable to increase the speed a certain reasonable amount. Incidentally it may be remarked that this indicates the advisability of developing maximum speed with minimum coal consumption by placing all similar vessels in continuous competition in steaming, much in the same manner that we utilize the competitive principle in developing their maximum gun-power. (3) That it is always desirable to substitute heavy turret guns, such as 12-inch, for the equivalent weight of the usual intermediate guns (6-inch, etc.); in other words, that the all-big-gun one-caliber ship affords the greatest possible capacity of effective hitting. (4) That in order to simplify fire-control, and attain its maximum efficiency, all of the main-battery guns of ships of whatever type should be of the same caliber. (5) That for similar reasons all of the torpedo defense guns should be of the same caliber. (6) That very important tactical advantages are obtained by the concentration of many heavy guns on each large vessel of high speed, and the consequent intense concentration of heavy-gun fire due to the tactics of the fleet. (7) That the tactical advantages of size, speed, and diminished numbers are of much greater importance than any advantages to be obtained from the in-

creased number of smaller and slower vessels that may be built at the same total cost.

In addition to the superior individual and tactical advantage of large vessels, they also possess the following minor advantages: (1) A fleet of ten 20,000-ton ships, each having a broadside fire of eight 12-inch guns, or eighty in all, would cost about $100,000,000. (2) A fleet of twenty smaller vessels, each having a broadside fire of four 12-inch guns, or 80 in all, would cost about $120,000,000 or $130,000,000 (though I previously assumed the cost of these fleets to be equal, in order to accentuate the tactical value of large ships). (3) It requires less men to man the main-battery guns on an all-big-gun ship than a mixed-battery ship; for example, it requires less men to serve the ten 12-inch guns of the "Dreadnought" than the four 12-inch and sixteen 6-inch guns of the "Missouri." (4) It will require no more men for the "Dreadnought's" crew than it would for the "Missouri's," if she had the full complement of men (as measured by European standards), which neither she nor any of our battleships have. (5) The complement of officers of the "Dreadnought" is not as great as should be that of the "Missouri" or "Louisiana," because the former requires one fire-control party, while the latter ships require respectively two and three parties, as well as more officers to command the guns. (6) Then assuming 800 men and 20 combatant officers in each ship, it would require 8,000 men and 200 officers for ten all-big-gun ships, and about 16,000 men and 400 officers for the fleet of small vessels having the same broadside fire. (7) It will cost nearly twice as much to dock as the ten large ones, and the latter can be docked in one-half the time, which is a great advantage in time of war. (Capt. Mahan notes that the absence of a big ship for docking, coaling, etc., reduces the strength of the fleet more than the absence of a small one, but he neglects to note that with twice as many ships in the fleet there will be twice as many absentees in a given time.) (8) From the above it is clear that the cost of maintaining a fleet of small vessels having the same broadside fire as a fleet of large ones (of double the individual broadside fire) will be nearly twice as much as that for a fleet of large vessels of about the same total manpower. (9) I understand that the cost of maintaining a battleship is near $1,000,000 a year; therefore, the yearly maintenance of a fleet of ten large vessels would cost about $10,000,000 less than that of the twenty smaller ones. (10) The final conclusion is, that for the sum that it would cost to maintain the twenty small battleships we could maintain a fleet of ten large ones, that would be greatly superior in tactical qualities, in effective hitting capacity, speed, protection, and inherent ability to concentrate its gunfire, and have a sufficient sum left over to build one 20,000-ton battleship each year, not to mention needing fewer officers and men to handle the more efficient fleet.—Engineering.

ENGINEERING NOTES.

Pneumatic locomotives are employed in some of the large German collieries. The engine is constructed like an ordinary steam locomotive. An air-storage tank takes the place of the boiler. The air is stored under pressure varying from 700 to 1,000 pounds per square inch. In some of the engines the air passes into an auxiliary reservoir before entering the cylinders. The air pressure is reduced to about 150 pounds per square inch before entering the engine cylinder. The air is used expansively by means of the Stephenson link-motion gear.—Compressed Air.

For simple cylinder locomotives, the superheaters now in use are designed so that they can be used with the old as well as the new locomotives, and adjusted to meet any boiler conditions without loss of boiler efficiency. For actual practice it is necessary to determine the exact expense for maintenance and possibility for failure of a superheater before it can be recommended, as any complication of parts liable to cause trouble should be avoided in locomotive practice. While tests so far made have been on locomotives operating in good water districts, it is believed that the large 5-inch, or greater diameter of flues containing the superheater pipes, will not give serious trouble, and while they need slightly more attention than the regular sizes of tubes, the decreased demand on the boiler reduces the amount of repairs needed by the latter sufficient to compensate for the additional work required on the larger tubes.

The question of fuel valuation which comes up when studying the comparative cost of power plants and their economics has different aspects. The present attitude is that the cheaper the fuel the less profitable it is to use gas power in a plant. If, therefore, a gas power plant cannot effect a saving in the cost of labor, supplies, and repairs, over what is obtained with steam, there will be a definite economic limit fixed which is determined by the price of fuel, and beyond which there is apparently no hope for gas power. Curves have been plotted showing diagrammatically the comparative cost of a gas and a steam installation. When first plotted they were equal for coal in the neighborhood of $2 per ton. A year later it was shown that the two cost lines crossed at a point corresponding to a value of coal of one dollar per ton. It has been suggested that a further reduction in the price of gas power machinery may eventually tend to effect a crossing of the two curves at the zero point of the cost of coal. This would mean that when fuel can be had for nothing, both plants can deliver power at the same cost.

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